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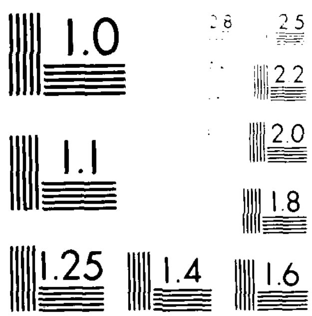
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AIR FORCE

HUMAN RESOURCES

OPERATIONAL TEST AND EVALUATION HANDBOOK FOR AIRCREW TRAINING DEVICES: OPERATIONAL SUITABILITY EVALUATION

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February 1982

Final Report

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The Public Affairs Office has reviewed this report, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.

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Contract Monitor

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Operations Training Division

RONALD W. TERRY, Colonel, USAF
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The Handbook is comprised of three volumes and is intended to provide guidelines and procedures appropriate for Air Force Operational Test and Evaluation (OT&E) personnel to use in planning, conducting and reporting the results of simulator assessment efforts. Although of value to all test personnel, it is primarily for the typical novice test manager/director—a person who has subject matter expertise (e.g., a qualified pilot or operator), but who may have little or no previous OT&E experience. The Handbook provides detailed coverage on OT&E planning and management with special emphasis on measuring device operational effectiveness and suitability. In accord with its objectives, the Handbook was prepared to serve as a supplement to Air Force Manual

Item 20 (*Continued*)

55-43, "Management of Operational Test and Evaluation," by providing those specific additional evaluation concepts and techniques necessary *for aircrew training device* test and evaluation.

PREFACE

This volume (Volume III. Operational Suitability Evaluation) is one part of a three-volume Handbook produced for the U.S. Air Force Human Resources Laboratory/Operations Training Division (AFHRL/OT). The Handbook is entitled, "Handbook for Operational Test and Evaluation (OT&E) of the Training Utility of Air Force Aircrew Training Devices." This effort has been accomplished by the Seville Research Corporation under Contract No. F33615-78-C-0063. Dr. Thomas H. Gray served as the Air Force Laboratory Contract Monitor (AFLCM) on the project. For Seville, Dr. William H. Hagin was Project Director, and Dr. Wallace W. Prophet was Program Manager.

The three volumes which comprise the total Handbook are intended to provide guidelines and procedures appropriate for use of Air Force ATD OT&E test team personnel in planning, conducting, and reporting the results of aircrew training device OT&E efforts. The three Handbook volumes are:

Volume I. Planning and Management

Volume II. Operational Effectiveness Evaluation

Volume III. Operational Suitability Evaluation

It is important that the reader understand that this Handbook was prepared to serve as a supplement to AFM 55-43, "Management of Operational Test and Evaluation" by providing those specific additional evaluation concepts and techniques necessary for ATD test and evaluation.

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CHAPTER 1

PURPOSE AND ORGANIZATION OF VOLUME III

INTRODUCTION

Volumes I and II of this Handbook provide guidance for the test director concerning how to plan for ATD OT&Es and how to conduct ATD operational training effectiveness evaluations. This volume is concerned with assessing the impact of operational suitability factors on ATD usefulness. Operational suitability factors pertain to how well the device meets accepted equipment serviceability requirements within its intended operating and maintenance environment.

There are two principal components of ATD suitability that must be examined during ATD OT&E, viz, hardware suitability and software suitability. Assessment of hardware suitability is important from the standpoint that OT&E findings in this area can significantly affect downstream ATD life-cycle costs, manning requirements, logistics support, and the ultimate instructional usefulness of the device. For example, a device may be rated highly with respect to operational effectiveness, but it will be of little use if it is not available for training because of its poor reliability or maintainability characteristics.

Software suitability assessment also has become a key element in ATD suitability evaluations, because modern digital ATDs have a substantial software component. Software is involved to a large degree in the simulation of dynamic flight characteristics and in procedural, navigational, communications, weapons, and electronic countermeasures (ECM) system functions, among others. Software also plays an important role in the control and functioning of ATD instructional support features (e.g., freeze, record/replay, reset, and auto-demonstration), as well as automated maintenance test features.

Management of ATD Operational Suitability Testing

Effective assessment of ATD operational suitability during OT&E depends upon careful advanced planning and skilled execution of the required testing activities. As will be seen in the detailed technical discussions of these testing activities which follow in Chapters 2 and 3 of this volume, no single person is likely to have the full range of expertise required either to plan for or to execute all of the technical efforts appropriate to ATD operational suitability testing. For this reason, two deputy test directors are responsible for the technical aspects of ATD operational suitability testing: One, the Deputy for Logistics Evaluation (DLE) is responsible for hardware suitability testing; the other, the Deputy for Software Evaluation (DSE) is responsible for software suitability evaluation.

Deputy for Logistics Evaluation (DLE). The Deputy for Logistics Evaluation (DLE)[1] and his team are under the operational control of the AFTEC or MAJCOM test director, and function in accordance with the pertinent provisions of the following documents: (1) AFR 80-14, "Research and Development Test and Evaluation;" (2) AFM 55-43, "Management of Operational Test and Evaluation;" (3) AFLCR 80-4, "Test and Evaluation;" and (4) AFTECP 400-1, "Logistics Assessment."

The DLE normally is a senior OT&E specialist from the Air Force Logistics Command (AFLC), and his team consists of a select group of logisticians, engineers, technicians, and other support specialists as required from the AFLC, AFTEC, and/or the MAJCOMs. The DLE and his team serve as the logistics test focal point in the accomplishment of the actions necessary to effect all suitability test planning and execution requirements.

Deputy for Software Evaluation (DSE). The Deputy for Software Evaluation (DSE) and his team also are under the operational control of the test director. The DSE and his team of software evaluators operate in general accord with those software evaluation guidelines and procedures which have recently been documented in a five-volume AFTEC handbook titled, "Software OT&E Guidelines." Volumes in this handbook set include the following:

I. Software Test Manager's Handbook

II. Handbook for Deputy for Software Evaluation

III. Software Maintainability Evaluator's Handbook

IV. Software Operator-Machine Interface Evaluator's Handbook

V. Computer Support Resources Evaluator's Handbook

PURPOSE OF THIS VOLUME

Even though the test director is dependent upon these two deputies (the DLE and the DSE) for the technical adequacy of ATD operational suitability testing, he must have a general understanding of the processes involved. This volume is intended to provide him with that understanding. Familiarity with the content of Volume III will help the test director by facilitating his interactions with the two suitability test deputies and their teams of specialists.

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[1]The term "Logistics Support Evaluation Team (LSET)" has been used in many earlier OT&E plans and reports. The current term "DLE" has replaced "LSET Chairman," but the same functions are performed.

ORGANIZATION AND CONTENT

This Handbook volume consists of three chapters and a number of appendices. This introductory chapter has emphasized the importance of ATD suitability testing. It has also pointed out that the technical complexity of hardware and software suitability testing necessitates the designation of two deputy test directors--one for each of the two areas. Chapter 1 concludes by emphasizing that the test director must have a basic familiarity with the details of hardware and software suitability testing, even though he depends upon his two deputies (the DLE and the DSE) for their actual accomplishment.

Chapters 2 and 3 provide the technical and methodological information that the test director needs to understand and manage hardware and software suitability testing. Chapter 2 addresses hardware suitability testing in terms of device reliability, maintainability, availability, logistics supportability, and operating and support costs. Chapter 3 discusses software suitability evaluation in terms of software maintainability and usability.

The discussions of each of the above listed sub-elements of hardware and software evaluation provide the test director with the necessary ATD OT&E oriented definitions of these factors and a required understanding of the methods used for their evaluation. Perhaps of even greater significance to the test director are those parts of the discussion which alert him to a number of specific concerns to which he should attend in the areas of "Phase of Test Considerations" and "Personnel Requirements."

Phase of Test Considerations

Estimates based upon OT&E data drive a number of critical decisions relating to funding/budget planning, manpower requirements, and planning for overall support of the system in its operational setting. The precision of those estimates is a matter of great concern to decision makers with respect to both operational effectiveness and operational suitability factors, because long-term budgetary, manpower and provisioning plans must often be made well in advance of actual need.

As shown in Figure 1-1, early in-plant IOT&E provides "rough" data relating to system effectiveness and suitability, data which can then be refined by later on-site IOT&E and FOT&E phases. Because the iterative nature of this process of "estimate, refine, and re-evaluate" is of particular importance to suitability considerations as testing progresses, in the discussions of the various suitability factors which follow, the section "Phase of Test Considerations" will include additional information that may be of use to the test director with respect to the specific evaluation element in question and the phase of test being supported.

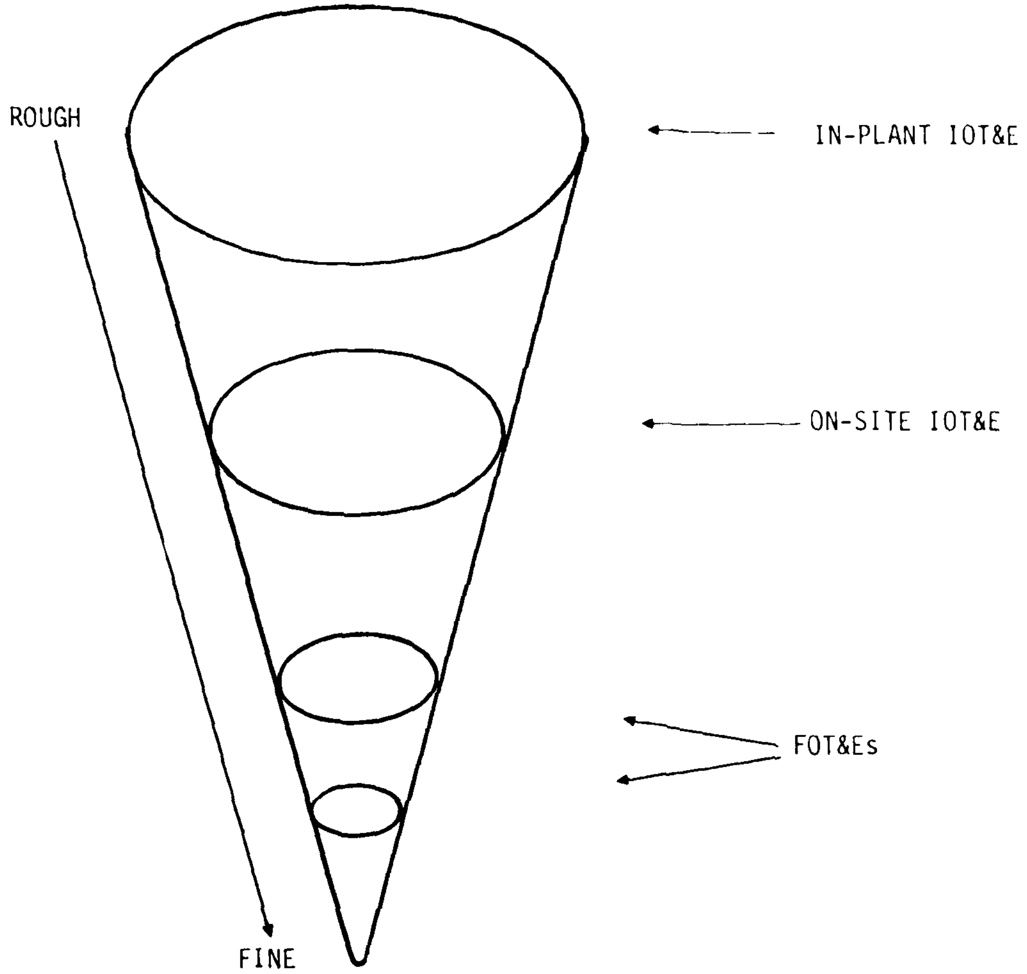

Figure 1-1. Precision of suitability estimates for successive phases of OT&E.

Personnel Requirements

As noted above, the test director depends upon his two deputies for support in planning, executing, and reporting ATD suitability evaluation activities. In most instances, personnel needs will be taken care of for him by these two personnel. However, there can be specific personnel requirements and/or characteristics of direct interest to him. Where appropriate, such personnel requirement concerns are surfaced in the concluding portion of each discussion.

CHAPTER 2

HARDWARE SUITABILITY TESTING

COMPOSITION OF LOGISTICS EVALUATION TEAM

As was pointed out in Chapter 1, responsibility for hardware suitability testing is assigned to the Deputy for Logistics Evaluation (DLE) and his team of specialists. The composition and command sources of the DLE team may vary with each individual test situation, but the following is illustrative of the usual team membership:

Position	Command source
Deputy Director for Logistics Evaluation	AFLC
Reliability and maintainability engineers (Note: In some cases, a simulator maintenance analyst may serve this function)	AFLC
Simulator technicians	MAJCOM
Technical data specialists	AFLC
Flight crews and/or instructors	MAJCOM

(Note: Resources, normally available because they are necessary for operational effectiveness evaluations, are used to exercise the ATD during suitability testing.)

Specific DLE Responsibilities

The Deputy for Logistics Evaluation is responsible for the following:

- Assisting the AFTEC or MAJCOM test director in preparing test plans and reports.
- Maintaining open communications through AFTEC with the ATD program office (SimSPO), MAJCOM, and AFLC.
- Assuring that written procedures are available for data collecting, processing, analysis, evaluation, and filing.
- Ensuring that DLE team members comply with all test procedures.

- Ensuring that data collected are adequate and thorough.
- Attending conferences, meetings, and demonstrations as required.
- Presenting logistics briefings as required.

ORGANIZATION OF THIS CHAPTER

ATD hardware operational suitability evaluations encompass a wide variety of concerns. Figure 2-1 shows the five major hardware suitability areas of concern and the subelements associated with each. The remainder of this chapter is organized into five major subsections in accord with this overall structure. In order of presentation, the evaluation concerns treated are:

A. Reliability;

B. Maintainability;

C. Availability;

D. Logistics Supportability; and

E. Operating and Support Costs.

To the extent practicable, the discussion for each major suitability element first defines that element in the context of ATD OT&E. Next, the discussion describes the evaluation methods to be used. Each subsection discussion then concludes by identifying practical guidelines that may serve to inform the test director of possible lead time requirements, phase of test specific concerns (i.e., IOT&E/QOT&E, FOT&E), or general aids to the successful accomplishment of the various operational suitability assessments.

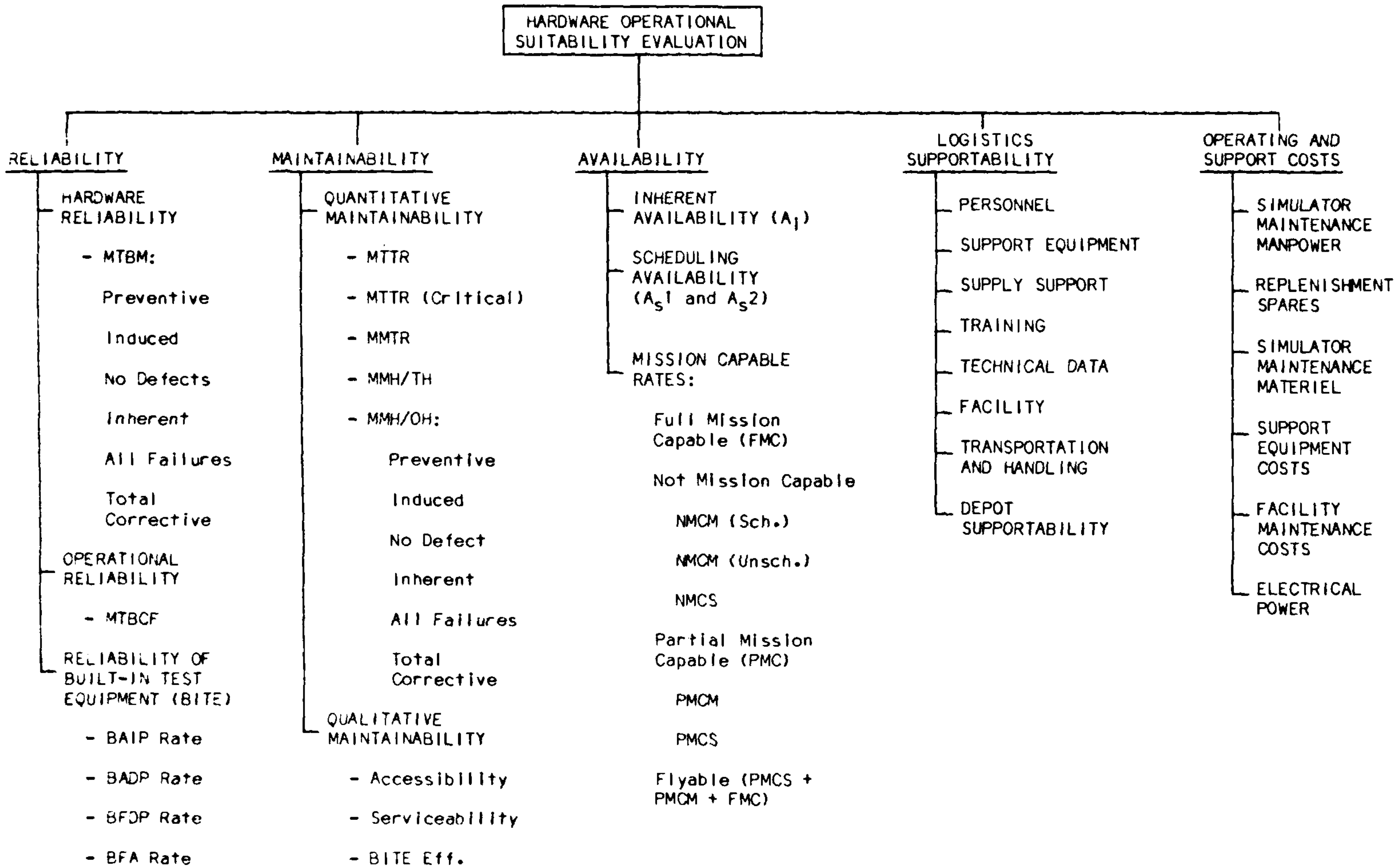

Figure 2-1. Elements of hardware operational suitability evaluation.

A. RELIABILITY

RELIABILITY EVALUATION ELEMENTS

Reliability is defined as the probability that a system will perform satisfactorily for a given period of time when used under stated conditions. Reliability thus relates to the frequency with which failures occur and the relationship of those failures to the mission of the system in question. In the case of ATDs, the mission is that of supporting aircrew training. ATD reliability, therefore, is an index of how satisfactorily the ATD and/or its major subsystems will hold up when used for training.

Three categories of ATD reliability are of interest--hardware (logistics) reliability, operational (mission) reliability, and the reliability of built-in test equipment (BITE). These categories are defined briefly below.

Hardware Reliability

Hardware reliability (or logistics reliability) refers to the identification of failure patterns or trends that may adversely impact the system's functioning and that will require excessive resources to restore the system to the required operating condition. Since the intent of the hardware reliability evaluation is to determine (or estimate) the downstream logistics impact of any maintenance occurrence in terms of spares requirements, maintenance manpower, or support test equipment, all maintenance occurrences are of interest.

Any maintenance actions on an ATD, including preventive maintenance, adjustments (e.g., CRT focus), light bulb burn-out, computer "glitch," etc., are referred to as occurrences. Occurrences that have to do with any system/component breakdown or deterioration such that normal system function is degraded are referred to as failures. Failures can be further classified as either critical or noncritical. A critical failure is a failure that causes a significant disruption to the ongoing training mission of the ATD. A noncritical failure is a failure of the system in an area or manner that does not affect the ongoing training mission. Thus, hardware reliability addresses the potential effects of all occurrences which can place a demand on the logistics support system, whether or not training mission capability is affected by the occurrence.

Operational Reliability

Operational reliability (or mission reliability) is a measure of the ability of an ATD to complete its planned training functions. As a consequence, only those "critical failures" (as defined above) that interrupt or degrade significantly the capability of the device to support specific planned or ongoing training activities are of interest in the determination of mission reliability.

Reliability of Built-in Test Equipment (BITE)

The reliability of BITE systems refers to the ability of those systems to detect and isolate failures. Examples of BITE include, among others, computer controlled preflight programs, indicator panels (open circuit breaker, system off, etc.), and computer system diagnostic programs.

RELIABILITY EVALUATION METHODS

There are two types of structured reliability evaluations.[1] The first type, known as the Fixed Length Test, requires that the system in question be run for a specified number of hours. If more than a predetermined number of failures occur during that period, the system fails the test; otherwise, it passes. The second type of test is known as the Probability Ratio Sequence Test (PRST). In this test, the system is operated for a specified minimum time. Beyond this point, determination is made as to which one of the three following conditions exists: (1) If an upper limit of failures has been exceeded, the system has failed the test; (2) if the number of failures is below some lower limit, the system has passed the test; or (3) if the number of failures is between the upper and lower limits, the test must continue. It is this second type of reliability test (PRST) that applies most often to ATD T&E in-plant.

For on-site OT&Es, a structured test program such as described above does not typically apply. The on-site operational environment itself provides a situation in which system failure data are recorded as they occur on a daily basis for the entire period of operational testing. In this way, a more credible prediction of mature system reliability may be achieved.

Data Collection Procedures

The data collection procedures for hardware and operational reliability evaluations are basically the same. Information about the occurrences used to compute reliability indices comes from the following sources:

---

[1] MIL-STD-781, "Reliability Design Qualification and Production Acceptance Tests."

- Reliability Demonstration Plan. This is the basic guideline for conducting the reliability test during QOT&E/IOT&E.

- Reliability Test Log. This record is used to recover data to assist in providing logistic support and to determine if the ATD meets reliability requirements.

- Component Removal Data. These data are used in determining the need for special tools, procedures and test equipment, tech data, special skills, etc. Such data include:

  -- Operating times

  -- Occurrence data

  -- Repair data

  -- Nonfailure removal data (includes instances in which there is indication that a component is defective or that a component has been replaced, but the problem still exists)

- Contractor Failure Data

- Correlated AFLC D056 Reports (these are historical data on equipment in the inventory)

- Debriefing Records

- USAF Service Reports (SRs)

- Maintenance Observation Forms (e.g., AFTEC Form 99, AFTO 349, or similar)

- Reliability and Maintainability Allocations, Assessments, and Analysis Report (DI-R-3535)

- Simulator Acceptance Deviation or Waiver Reports (or like reports)

- Logistics Support Analysis Record (LSAR)

Reliability Test Log. The principal means of collecting reliability data is the Reliability Test Log. Collection of reliability data involves two basic elements or parts. The first of these is a chronological account of events, e.g., operating on- and off-times, times of occurrences or failures, and maintenance times. An example of a Reliability Test Log is depicted in Figure 2-2. (The features of the specific ATD under test will dictate the precise format of the log headings.)

A separate Reliability Log sheet is filled out for each day of the reliability test. An event number is assigned to each maintenance action. That event number is based on the date/event sequence and is used to aid in relating the chronological accounting in the supporting maintenance observation reports used to gather more detailed maintenance action information. Some logs will be "full," indicating a high number of occurrences during a day (Figure 2-3), while others will be nearly "empty," indicating a relatively low number of occurrences (Figure 2-4).

Maintenance Observation Reports. The second data element supporting reliability determinations is derived from maintenance observation reports.[1] (Either AFTEC Form 99 or AFTO Form 349 can be used for this purpose.) AFTEC Form 99 is shown in Figure 2-5.

Information contained on the maintenance observation report is used as the principal source for later maintainability, tech data, spares, personnel, facility, etc., determinations. Information shown also includes How-Mal codes (IAW AFTO 43-1-06-2), maintenance type codes, time to restore, and other critical data.

Maintenance observation reports are normally filled out by DLE maintenance personnel for each maintenance action performed. In some cases, such as tests with contractor maintenance, the ATD contractor can be required to fill out the necessary maintenance record forms.

BITE reliability data collection. To calculate the required BITE rates, it is necessary that appropriate notations are made on the reliability log and maintenance observation reports. In some cases, a separate BITE log may be more applicable (see Figure 2-6). Those notations consist of coded entries to the log, immediately following the description of the occurrence. Refer to Appendix A for a listing and definition of the BITE rate codes.

Categorization of data. Occurrences during any in-plant reliability evaluation must be classified as to whether they are countable or noncountable occurrences. This is necessary to ensure that only countable occurrences are included in the calculations of reliability indices. This categorization may occur at the time of the occurrence or later, at the discretion of the DLE. The two categories are as follows:

---

[1] There forms are also commonly known as Support Evaluation Worksheets.

RELIABILITY TEST LOG

DATE: SHEET ___ OF ___

Time taken	#1 Sim. time	#2 Computer	#3 Visual	#4 Video	#5 Day/Dusk	#6 Night

1 TIME	2 EVENT	3 INIT.	4 REMARKS

Figure 2-2. Sample reliability test log.

ARPTT RELIABILITY TEST LOG

DATE: 07/11/79 (311)　　　　SHEET ___ OF ___

Time taken	#1 Sim. time	#2 Computer	#3 Visual	#4 Video	#5 Day/Dusk	#6 Night
0600	11388.9	8634.9	7918.2	6577.8	3478.3	4622.5

1 TIME	2 EVENT	3 INIT.	4 REMARKS
0600	Power up and start checks		
0640	Start preflight		
0705	Finish preflight		
0730	Finish checks		
0753	Mission #1 cancelled		no show
0800	Maj. Roy flying sim for George who is investigating spoiler response		
0810	George finished		
0915	Adjust CCU blanking		JCN #2840122
9030	Mission #2 cancelled		no show
1030	Start Mission #3		
1156	Adjust CCU blanking by request		JCN #2840122
1200	End Mission #3		
1205	Start Mission #4		
1226	Motion bump, to right, then left		During Auto Demo 69 between 1.5 & 2 min. playback.
1300	Record/Replay wouldn't replay		Everything was normal; had come off auto/demo a few min. earlier
1325	Record/Replay functions OK now		
1330	Mission #4 ends		
1335	Mission #5 start		
1455	Mission #5 end		
1500	Mission #6 start		
1600	End Mission #6		
1605	Start tour		
1610	Boom glitch		Vertical
1800	Start verifications		
2200	Stop verifications		

Figure 2-3. Example reliability test log showing a number of occurrences.

RELIABILITY TEST LOG

DATE: 07/11/79 (310) SHEET 1 ___ OF ___

Time taken	#1 Sim. time	#2 Computer	#3 Visual	#4 Video	#5 Day/Dusk	#6 Night
0600	11372.3	8618.3	7001.7	6561.3	3462.7	4606.6

1 TIME	2 EVENT	3 INIT.	4 REMARKS
0600	Power up and daily checks		
0630	Start preflight		
0645	Finish preflight		
0730	Adjust visual and finish checks		
0740	Start Mission #1		
0855	Mission #1 ends		
0855	Changed from "H" to "G"		
1040	Mission #2 No-show		
1045	Mission starts(#3)		
1430	Mission #3 ends		
1435	Start Mission #4		
1700	End Mission #4		
1701	Start verifications		
2200	Stop verifications		

Figure 2-4. Example reliability test log showing no occurrences.

SUPPORT EVALUATION WORKSHEET

1. JOB CONTROL NO.	2. TECH DATA	3. CRITICALITY	4. CLOCK TIME	5. FLIGHT NO.	6. MAINT LEVEL
7. ITEM IDENT	8. SERIAL NO.	9. REFERENCE	10. WHEN DISC	11. DATE COMPL	12. DISPOSITION

13. FAILED ITEM					
a. NOUN	b. SERIAL NO.	c. PART NO.	d. WUC	e. HOW MAL	f. FAIL CODE

14. DESCRIPTION OF DISCREPANCY OR MAINTENANCE TASK

	15. OBSERVED TASK						16. ESTIMATED TASK					
	AFSC A	SUP B	NO. C	TIME D	WUC E	ACTN TAKEN F	AFSC A	SUP B	NO. C	TIME D	WUC E	ACTN TAKEN F
1												
2												
3												
4												
5												
6												
7												
8												

17. FAULT ANALYSIS PROCD	18. PROCEDURES	19. BITE	20. TOOLS/SE
21. REEVALUATION REQUIRED ☐ YES ☐ NO	22. RATING	23. MAINT TYPE	24. TIME COMPLETED

25. CORRECTIVE ACTION

COMMENTS (Use reverse, if necessary)

EVALUATOR

AFTEC FORM APR 78 99

Figure 2-5. Example maintenance observation report. (AFTEC Form 99 is shown. AFTO Form 349 can also be used.)

______________ DIAGNOSTIC TEST LOG

DATE	TIME	DIAG PGM/ ROUT/MODULE	RUN TIME	BITE CODE	COMMENTS

Figure 2-6. Example BITE log.

- Countable Occurrences. Those occurrences on operationally configured equipment which the test team determines to be representative of occurrences that might happen in the operational environment.

- Noncountable Occurrences. Those occurrences which are unique to the test environment and which are not representative of the operational environment. For example, failures which might be attributable to deficiencies of an in-plant test environment, such as inadequate air conditioning, would be categorized as noncountable.

Reliability Indices

Mean time between maintenance action (MTBM) and mean time between critical failures (MTBCF) are the two principal measures of reliability determined during reliability evaluations. MTBM indices have to do with the hardware reliability of the device, and MTBCF indices relate to the operational reliability of the device. The hardware and operational reliability determinations are calculated by the DLE reliability/maintainability engineer.

Hardware reliability. There are six versions of the MTBM described in following paragraphs, all of which are calculated by dividing operating time by the total number of on-equipment maintenance occurrences, where operating time is defined as the system elapsed time indicated (ETI). The formula used to calculate MTBM is shown in Appendix A. The six versions of MTBM are as follows:

1. MTBM (preventive): This form of MTBM considers preventive on-equipment occurrences during the active test. (Adjustments, checking fluid levels, "tweaking" drifting indicators, etc.)

2. MTBM (induced): This form of MTBM considers all on-equipment occurrences resulting from an item no longer meeting performance requirements because of an induced condition. An induced condition is defined as a condition resulting from an external source, e.g., power fluctuation, environmental conditions, or operational error. Examples of operational errors would be the execution of an improper on-equipment preventive maintenance action.

3. MTBM (no defect): This form of MTBM considers on-equipment occurrences resulting from a non-defect condition. These are "false alarm" occurrences. An example of a false alarm would be an apparent failure such as might be indicated by operator error/confusion or in a number of component areas when a failure of a power supply occurs.

4. MTBM (inherent): This form of MTBM considers all on-equipment occurrences resulting from an item no longer meeting performance requirements due to an inherent condition. An inherent condition is defined as a condition resulting from an internal degradation of a component. A common example would be a degradation in IC "chip" function due to a defective batch or due to heat. Once the defective chips were replaced, the system would function normally. MTBM (inherent) on-equipment occurrences are computed using all How-Mal codes excluding those for MTBM (induced) or MTBM (no defect).

5. MTBM (all failures): This form of MTBM considers all on-equipment failures and refers to all failures considered in MTBM (inherent), MTBM (induced), and MTBM (no defect).

6. MTBM (total corrective maintenance): This form of MTBM considers on-equipment occurrences of MTBM (inherent) and MTBM (induced).

Operational reliability. The Mean Time Between Critical Failures (MTBCF) is an index of the operational mission reliability of the ATD. MTBCF is the total operating time during the evaluation divided by the total number of critical failures during that time.

As defined earlier, a critical failure is one that degrades the specified ongoing training mission of the device. When a failure occurs, the instructor/operator pilot at the trainee station is consulted to determine whether the failure had a significant impact on the training mission occurring at that point in time. An example of a critical failure would be a failure in the Horizontal Situation Indicator during instrument training. Such a failure would impact the ongoing training mission, and, thus, would be categorized as a "critical failure." A failure in the ATD visual system, however, probably would not have affected the ongoing instrument training and, therefore, would not be classified as a "critical failure." See Appendix A for more discussion on MTBCF calculation and critical failure distinctions.

Built-in Test Equipment (BITE) reliability. Quantitative indices of the ability of BITE to detect and isolate failures accurately are expressed in terms of various BITE rates. The following BITE rates are calculated. Computational formulas for these BITE rates are contained in Appendix A:

- BAIP rate (BITE accurately isolated problem) is the effectiveness of the system both to detect a failure and to determine what failed.

- BADP rate (BITE accurately detected problem) is the effectiveness of the system to identify that a particular failure has occurred.

- BFDP rate (BITE failed to detect problem) is the occurrence rate of failures that should have been determined by BITE but were not.

- BFA rate (BITE false alarm) is the occurrence rate of BITE identifying failures erroneously.

Two of the identified reliability indices are of particular interest to the ATD OT&E test director: (1) the overall hardware reliability index, MTBM-all failures and (2) the operational reliability index, MTBCF. After these two values have been calculated, they are compared with the reliability criteria levels as defined in the Reliability Test Plan: e.g., Threshold, Standard, and Goal. Two actions are normally undertaken following instances where the data yield a reliability value less than threshold value: (1) further reliability analysis; and/or (2) submission of a Service Report (SR). The purpose of the follow-on reliability analysis is to identify the subsystem, equipment, or component which is the principal contributor to or direct cause of the reliability problem. The Service Report is the official means of notifying the SimSPO of a deficiency and has as its purpose the initiation of corrective action to resolve the problem. SRs remain "active" until cleared by whatever corrective action is determined to be appropriate. The remaining five reliability indices--preventive, inherent, induced, no defect, and total corrective--are principally of use in validating and refining previously developed estimates (see Figure 2-7, Example reliability reporting table).

RELIABILITY MEASURE	VALUE (HOURS)	THRESHOLD	STANDARD	GOAL
MTBCF	45.2	17.2	39.0	49.0
MTBM (Preventive)	15.0			
MTBM (Induced)	115.8			
MTBM (Inherent)	25.3			
MTBM (Total Corrective)	19.3	12.3	21.5	43.0
MTBM (No Defect)	50.7			
MTBM (All Failures)	12.5			

Figure 2-7. Example reliability reporting table (example shows hypothetical data). Note: Formats for reporting should follow current AFR 80-5 "Reliability and Maintainability Programs for Systems, Subsystems, Equipment, and Munitions."

Supplementary reliability data for equipment items which exhibit high failure rates during the evaluation period and which are presently in the USAF inventory can be obtained from the AFLC D056 product performance system data bank and AFLC G026 Material Improvement Program (MIP) report(s). Correlation of the OT&E data with those historical data can aid the DLE test team in making more accurate estimates of system and subsystem reliability.

RELIABILITY: TEST DIRECTOR CONCERNS

Phase of Test Considerations

Test and field data covering a variety of systems have indicated that, if the system is mature, the failure rate will be relatively constant throughout its programmed operational life cycle. When equipment is produced and first introduced into the inventory, there are usually more failures during a debugging or burn-in period. Likewise, when the equipment reaches a certain age, there is a wearout period during which failure rates increase. A typical failure-rate curve illustrating this point is depicted in Figure 2-8. In accord with this relationship, reliability assessments early in a systems operational life are likely to result in lower MTBM and MTBCF indices than would actually be the case when the system matures. In-plant test data, for example, will likely show lower system reliability than data collected during subsequent on-site tests. One approach for dealing with the problem of estimating mature system values is to compile separate data for the latter portion of the overall test period.

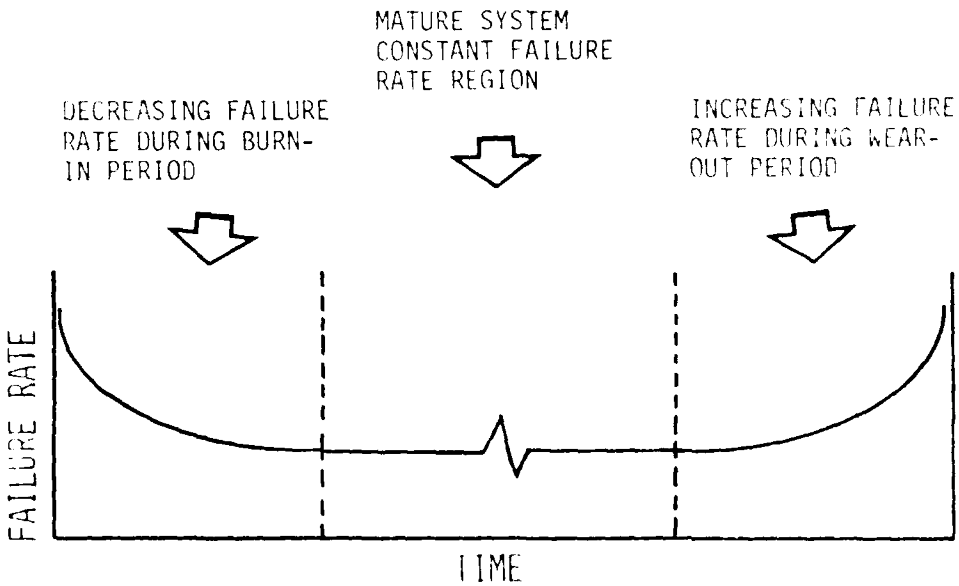

Figure 2-8. Typical failure rate curve.

In some cases, improvement in mature system values may be attributable to fewer failures and malfunctions in a single critical subsystem, e.g., computer system, visual system. ATDs frequently incorporate subsystems from various manufacturers. If the reliability of one of those critical subsystems is low during early test phases because of faulty components, defective cabling, etc., it is likely that attention by the appropriate contractor's technical representative will alleviate the problem for later test phases.

Personnel Requirements

A number of factors have an impact on the numbers and types of personnel that will be required for reliability determinations during ATD OT&E. Among others, these include device complexity and configuration, phase of test, number of test items, and site of test. In general, the following guidelines apply; however, these personnel guidelines must be modified by the test director as appropriate for his particular circumstances:

SPECIALTY	SOURCE	AFSC	NUMBER
DLE	AFLC or MAJCOM	66170 34100	1
Reliability & Maintainability (R&M) Engineer	AFLC	2895	1
Flight Sim Tech	MAJCOM	34174	1/station/shift
Offensive Sim Tech	MAJCOM	34176	1/station/shift
Defensive Sim Tech	MAJCOM	34172	1/station/shift

For in-plant tests (e.g., combined DT&E/IOT&E), the reliability demonstration (conducted by ASD) normally occurs at the end of the total acceptance/qualification test period. An AFLC reliability engineer is not needed for the total test period, but only for the reliability demonstration. A test may be scheduled to last about a month, but because of slippages in the program and ongoing engineering development on the device, it may run three or four times that long. Proper resource identification and TDY scheduling/budgeting are particularly important in this case, because a lengthy slip in the reliability demonstration can create a drain on limited TDY funding resources.

The reliability demonstration is not always conducted in-plant In some instances, the Air Force may conduct it after the device has arrived on-site. In this case, the reliability demonstration would actually be accomplished on-site as the last event prior to acceptance (DD 250 sign-off).

A Logistics Command reliability engineer is typically required only for the structured reliability demonstration. A reliability engineer is not normally required for extended on-site IOT&E or FOT&E period of testing. However, it should be noted that, prior to the start of test, a reliability engineer should be consulted to assure that adequate data collection procedures have been defined.

B. MAINTAINABILITY

MAINTAINABILITY EVALUATION ELEMENTS

There are two basic kinds of maintenance activity. The first, corrective maintenance, occurs whenever a system component or function has failed and requires subsequent repair or restoration. The other type, preventive maintenance (or scheduled maintenance), occurs on a regular basis and is intended as a means of reducing or preventing unplanned downtime for corrective maintenance.

Maintainability is concerned with those characteristics of system design and installation which affect the ease or difficulty of these maintenance actions--corrective and preventive--so that the system may be restored to, or retained in, a specified working condition. Requirements for maintainability considerations are formalized in Military Standards 470 and 471 and are imposed on all contractors supplying equipment to the military.[1,2]

ATD maintainability and reliability are closely interrelated in determining the overall suitability of a system. It is possible, for example, to have a system that meets its reliability requirement in terms of number of failures, but does not meet the maintainability requirement in terms of the time required to restore the system to operational status. Therefore, inclusion of maintainability evaluations during ATD OT&Es is an essential part of the evaluation of ATD operational suitability.

Quantitative Maintainability

There are two categories of maintainability of interest during ATD OT&E. The first of these, quantitative maintainability, is defined as a measure of the maintenance time and resources required to keep an item operating. Quantitative maintainability evaluations include computations of mean time to repair (MTTR), maintenance manhours per operating hour (MMH/OH), mean manhours to repair (MMTR), maintenance manhours per mission (MMH/M), maintenance manhours per training hour (MMH/TH), and maintenance hours per action taken code (i.e., the portion of total corrective maintenance time spent on each action taken category: troubleshooting, repair, adjustment, remove and replace, and no defect). These indices provide the test director

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[1] MIL-STD-470, "Maintainability Program Requirements."

[2] MIL-STD-471, "Maintainability Verification/Demonstration/Evaluation."

with a numerical basis for drawing conclusions about the overall maintainability of the ATD in question and serve to highlight those areas that may require further study.

Qualitative Maintainability

The second category of maintainability, qualitative maintainability, refers to those areas of system maintainability that must be evaluated by qualitative judgments. For example, item location accessibility, safety hazards, and "serviceability" would be of concern in qualitative maintainability evaluations. Human factors concerns--e.g., weight, handles, height above ground level--would also be pertinent in the qualitative evaluation. Guidelines for maintainability human factors considerations are contained in MIL-STD-1472, "Human Engineering Design Criteria for Military Systems, Equipment, and Facilities," Section 5.9 of which covers the following maintainability design guidelines:

- Mounting of components within units
- Adjustment controls
- Accessibility
- Lubrication
- Unit cases and covers
- Access openings and covers
- Fasteners
- Unit design for efficient handling
- Mounting
- Retaining devices
- Conductors
- Connectors
- Test points
- Test equipment
- Failure indications and fuse requirements
- Gas and fluid line identification

MAINTAINABILITY EVALUATION METHODS

The DLE should review all maintainability test plans to ensure that the planned testing and data recovery procedures are sufficient to allow for an adequate assessment of quantitative and qualitative corrective and preventive maintainability concerns. The DLE team should actually observe contractor maintenance tasks during maintainability evaluations to ensure that available technical data and proper support equipment are being used and that all repair data are being thoroughly and accurately recorded.

Quantitative Maintainability Evaluation Procedures

Depending on the user's concept of maintenance--Air Force or contractor--early OT&E (IOT&E or QOT&E) maintainability determinations may be conducted either in-plant or on-site. If organic Air Force maintenance is planned, the maintainability evaluation will normally be conducted on-site in its intended environment with representative Air Force maintenance personnel. If contractor logistic support (CLS) is planned, the maintainability evaluation will normally be conducted in the contractor's facility. Two sources of maintainability data may be combined to support early OT&E estimates in this area. The first of these is the structured maintainability demonstration (M-demo) conducted by the SimSPO during device DT&E or QT&E. The second source is those maintainability data resulting from maintenance actions performed during other periods of test (e.g., reliability testing, operational effectiveness testing, etc.).

M-demo procedures. The following is a description of the basic procedures followed in the structured ASD maintainability demonstration. However, collection of data during other periods usually follows the same basic methods of observing maintenance actions and recording relevant information on a standardized maintenance observation record form (e.g., AFTO 349). The principal difference is in the source of "faults." Instead of inserting preselected faults for evaluation as is done in M-demo, observations during other occasions are based upon those "natural" faults and malfunctions that may occur.

In gathering data to assess the device's maintainability during M-demo in the early phases of OT&E, one or more preselected faults are inserted into the equipment with the maintenance team absent from the area. The faults inserted are identified in a set of "failure data forms" supplied by the contractor, and approved by the SimSPO. Figure 2-9 illustrates the format and content of these forms. Once a fault has been inserted and verified, the maintenance team enters the area and initiates the appropriate corrective maintenance action. An independent observer uses a stop watch and a test observer recording form (AFTEC 99, AFTO 349) to record the time required for each step in the maintenance process.

MAINTAINABILITY DEMONSTRATION

CORRECTIVE MAINTENANCE TASK TO BE DEMONSTRATED

FAILURE NO. 1

NOMENCLATURE:

Matrix board (VASI drive)
A 74/489/600-620

LOCATION OF FAILURE:

Maintenance rack

FAILURE INSERTED:

Remove board
Lift off link between T35 and AA33

TYPE OF FAILURE INSERTED:

Failure of matrix board due to open circuit condition

SYMPTOMS:

No VASI motor drive effective on VASI 1.b., (parallel)
Prism may exhibit hue neither red nor white

ESTIMATED REPAIR TIME: 43 minutes

Figure 2-9. Example contractor provided maintainability failure data form.

Separate data sheets are filled out for each corrective task or simulated failure. The failure data forms and the completed test observer record forms constitute the bulk of the maintainability demonstration raw data. It should be noted that some portions of the data collected on these forms are quantitative, (e.g., time), whereas other portions are qualitative (e.g., use of tools, test equipment, etc.).

In some cases, failure to meet time standards for restoring the system to operation can be traced to support factors such as an excessive use or lack of technical documentation, test equipment, or other unproductive time use. These factors should be addressed under logistics supportability assessments.

The above described data gathering procedure applies to both corrective and preventive M-demos. Time data for preventive maintenance tasks being evaluated are recorded in the same manner and on the same forms as are used for "simulated" failures, except that the maintenance team is instructed to initiate a specified preventive maintenance routine as opposed to a corrective maintenance action.

Maintainability testing typically lasts a minimum of two weeks, during which time a number of corrective and preventive maintenance tasks are demonstrated. Usually the majority of the tasks to be demonstrated were randomly selected in advance by the SimSPO from a larger set of tasks. However, in addition to the randomly preselected tasks, the Air Force often may select a number of additional maintenance tasks for demonstration purposes.

As noted earlier, the OT&E maintainability evaluation includes both data resulting from the structured M-demo and data resulting from natural maintenance actions. Later FOT&E focuses exclusively upon maintenance actions resulting from natural faults and malfunctions as they occur.

Quantitative Maintainability Indices

Mean time to repair (MTTR) and maintenance manhours per operating hour (MMH/OH) are the two primary measures of effectiveness which result from the quantitative reliability evaluation. Other measures are mean manhours to repair (MMTR) and maintenance manhours per training hour (MMH/TH). Computational formulas for these measures are contained in Appendix B.

Mean time to repair (MTTR). MTTR is the total corrective maintenance clockhours during the test period divided by the total corrective maintenance actions over that same period. (Certain guidelines have been developed regarding which times to include in MTTR calculations. These guidelines are contained in Appendix B.) Time is usually reported to the nearest tenth (0.1) hour.

MTTR (critical). This is a measure of the corrective manhours expended on critical failures divided by the number of critical failures. This provides the average time to repair a critical failure. Maintenance crew size is not considered. Separate MTTR (critical) values may be compiled for certain device subsystems in addition to the device as a whole. For example, visual system, motion system, computer system, and instructor/operator station usually are compiled as separate entities.

Mean manhours to repair (MMTR). MMTR is the total corrective maintenance manhours during the test period divided by the total corrective maintenance actions over that same period. The time guidelines specified for MTTR apply (see Appendix B).

Maintenance manhours per training hour (MMH/TH). MMH/TH is the total of all maintenance manhours expended during operational testing divided by total number of hours the ATD was used for operational training (simulated or actual) during that testing period. In addition to the time guidelines specified for MTTR, some additional considerations are defined (see Appendix B).

Maintenance manhours per operating hour (MMH/OH). MMH/OH is the total direct maintenance manhours divided by the total operating time of the system. Maintenance manhours are the total of the direct maintenance manhours expended during operational testing times (e.g., reliability demonstration and operating effectiveness testing) on those occurrences listed under MTBM. Operating hours are the total of the system power-on hours during the operational testing times. Manhours are reported for both on- and off-equipment expenditures. MMH/OH is calculated for all manhours expended in the six basic categories of maintenance occurrences (Preventive, Inherent, Induced, No Defect, All Failures, and Total Corrective), and also for inspection and support general expenditures.

Once calculated, the results of quantitative maintainability measures are evaluated with respect to the threshold, standard, and goal criteria established in the test plan (assignment of evaluation criteria normally applies only to the MTTR and MTTR [critical] measures). Figure 2-10 shows an example of how these values may be reported. For those items causing below threshold values, comparisons should be made to corresponding reliability data, and a prioritized list of candidates for corrective action should be developed. At this point, consideration is given to the practicality/feasibility of correcting the condition, and a service report (SR) may be submitted as a result of this consideration.

Qualitative Maintainability Data Collection Procedures

As noted earlier, qualitative maintainability determinations have to do with accessibility, serviceability, ease of maintenance, human

MAINTAINABILITY MEASURE	TOTAL TEST	MATURE SYSTEM	THRESH-OLD	STAN-DARD	GOAL
MTTR	1.50	1.01	4.0	1.5	0.7
MTTR (critical)	4.35	1.98	4.0	1.5	0.7
MTTR	3.10	1.58			
MMH/TH	0.43	0.34			
MMH/OH					
- Preventive	0.20	0.24			
- Induced	0.03	0.02			
- No Defect	0.01	0.02			
- Inherent	0.21	0.10			
- All Failures	0.19	0.13			
- Total Corrective	0.31	0.15			
SUBSYSTEM MTTR (critical)					
Computing system	8.60	0.88			
Visual system	3.96	2.39			
Motion system	1.23	1.10			
Instructor stations	3.15	2.85			

Figure 2-10. Maintainability reporting format (hypothetical data).

factors, etc. The judgments made during this type of evaluation are not necessarily supported by strict quantitative criteria; they require that the evaluator utilize his expertise and experience. Emphasis is placed on identifying equipment design and installation characteristics that have potential for causing maintenance difficulties or safety hazards. Therefore, each deficiency or potential deficiency must be assessed on a case-by-case basis. In cases where problems are identified with accessibility and location, it may be possible to substantiate resulting SRs with quantitative data. Often still/motion pictures or video taping may prove useful.

The procedure employed to gather qualitative maintainability information is implemented by the Maintainability Evaluation Checklist. An example of such a checklist is provided in Appendix B. Elements of that checklist can vary significantly in detail or generality. In OT&E, the DLE team reliability/maintainability engineer manually compiles and analyzes the required data.

<u>Built-in test equipment (BITE) effectiveness.</u> Bite effectiveness refers to the impact of BITE on the maintainability of the system. The various BITE rates compiled under BITE reliability assessments should be assessed to determine areas where BITE significantly enhances or degrades ease of maintenance actions. This is primarily a qualitative assessment based upon the types of BITE available and those maintenance actions to which they apply.

MAINTAINABILITY: TEST DIRECTOR CONCERNS

Phase of Test Considerations

As noted in the reliability subsection, test and field data have indicated that such measures on "mature" systems are normally improved over measures taken when the system is first introduced into the inventory. Improvement in mature system maintainability values can be expected also to occur. As familiarity is gained with the system and common maintenance actions are defined, along with properly developed maintenance technical data, the mean time required to repair the system should decrease, thereby resulting in improved overall MTTR and MMH/OH measures.

The technique of compiling separate data for the latter portion of the overall test period may also be employed to estimate mature system maintainability. Figure 2-9, presented earlier, portrays how these data can be displayed for comparison purposes.

Personnel Requirements

Because maintainability tests normally occur subsequent to reliability tests during combined testing, the personnel requirements to accomplish maintainability assessments are not usually of concern. Additional simulator technicians are not normally needed because the same people required to support reliability assessments may be utilized for maintainability tests. It is important that these personnel be as familiar as possible with the maintenance tasks under test. The following personnel guidelines generally apply:

SPECIALTY	SOURCE	AFSC	NUMBER
DLE	AFLC or MAJCOM	66170 34100	1
Reliability & Maintainability (R&M) Engineer	AFLC	2895	1
Flight Sim Tech	MAJCOM	34174	1/station/shift
Offensive Sim Tech	MAJCOM	34176	1/station/shift
Defensive Sim Tech	MAJCOM	34172	1/station/shift

As was the case with the reliability engineer during reliability testing, the maintainability engineer is not needed during the total test period. He is needed only for the maintainability demonstration during combined testing. During FOT&E, a senior logistics person may be substituted and given responsibility for maintainability determinations. However, during FOT&E, maintainability observation may necessitate augmenting manpower during such observation periods depending on device complexity and extent of test requirements.

C. AVAILABILITY

AVAILABILITY EVALUATION ELEMENTS

The availability of an ATD is a function of its combined reliability, maintainability, and logistics supportability. From the standpoint of the user, ATD availability measures reflect the readiness of the ATD to perform its specific training mission at any given point in time. Availability is, therefore, the measure of greatest interest to the operational users of ATDs.

There are two basic kinds of availability addressed during ATD OT&E: Inherent Availability (A_i) and Scheduling Availability (A_s). In addition to these two kinds of availability determinations, Mission Capable Rates (MCRs) are of interest during ATD suitability evaluations. The following paragraphs discuss availability assessment procedures (A_i and A_s) and MCR determinations.

Inherent Availability

Inherent availability (A_i) is defined as the probability that the simulator will operate satisfactorily at a given point in time. Inherent availability measures provide preliminary information on the potential availability of the device. The term "potential" is used here because inherent availability assumes an artificial environment in which there are no logistics delays, free time, administrative time, or storage time. Inherent availability is a measure of the built-in availability of the device.

Scheduling Availability

Scheduling availability (A_s) may be defined as the probability of completing any scheduled training mission. Two forms of A_s are used: The first, A_s1, is the ratio between completed missions and scheduled missions; the second, A_s2, is the ratio between hours flown and hours scheduled. It goes beyond inherent availability to include the actual environment with its scheduling and logistics delays.

Mission Capable Rates

Although not an availability estimate in the pure sense, mission capable rates (MCR) are also a critically important aspect of ATD availability concerns. Mission Capable Rates predict the percentage of possessed time that a device can be expected to be usable for training, i.e., mission capable. In this sense, MCR determinations can provide a truer picture of device availability in the context of its operational training environment.

AVAILABILITY EVALUATION METHODS

Inherent Availability

Reliability (MTBCF) and maintainability (MTTR) data are used to calculate A_i for the overall system and its major subsystems. The data collection procedures, definitions, criteria, and miscellaneous factors described under the preceding reliability and maintainability sections also apply to these calculations. System MTBCF and MTTR of critical failures are used. If system A_i is less than threshold, A_i is calculated for critical subsystems to determine which subsystem is responsible for the low A_i. The components causing the low A_i are then identified and, using the A_i, MTBCF, and MTTR figures as justification, a service report (SR) may be submitted. Typical threshold values for availability are displayed in Figure 2-11.[1] Inherent availability indices are reported in all interim and final OT&E reports. Figure 2-12 shows an example of how A_i data may be formatted in final reporting.

Scheduling Availability

Scheduling availability determinations will be based solely on data from those times when the simulator is undergoing integrated mission testing. The DLE reports scheduling availability usually on a weekly basis. A preprinted mission schedule is required by the logistics technicians. This schedule should show the types of missions and the hours scheduled per type of mission. The instructor pilot (IP) determines whether a training mission was successful, or what portion of the mission was successful. Only those training missions which occurred during full system operational tests are counted as scheduled or successful missions. All scheduled training time lost is counted, including losses due to maintenance, operations "cancels" or "no shows," software, and facilities. A_s1 and A_s2 value are calculated, based on the data provided on mission scheduling, using the formulas in Appendix C.

Scheduling availability may be calculated for each type of mission flown in the simulator. Reasons for less than threshold A_s are analyzed. Causes of the low A_s are sought from examination of the reliability and maintainability data. Causes of the low A_s are identified, and a new A_s calculated whenever the cause of a given low A_s has been corrected. Service reports are then submitted as required.

The DLE reports overall simulator and mission-type A_s values to the OT&E test director. Scheduling availability data are included in the final report. Figure 2-13 provides a sample format for reporting these data.

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[1] Appendix C contains the computational formulas for all availability determinations.

MOE	THRESHOLD	STANDARD	GOAL
A_i	85%	95%	96%
A_s1	85%	90%	96%
A_s2	85%	90%	96%

Figure 2-11. Availability evaluation criteria (typical).

	TOTAL TEST	MATURE SYSTEM	THRESH-OLD	STAN-DARD	GOAL
A_i	93.7%	98.0%	85%	95%	96%
Subsystems A_i:					
Computing system	96.5%	98.9%			
Visual system	98.7%	98.9%			
Motion system	99.9%	99.9%			
Miscellaneous	98.0%	99.1%			

Figure 2-12. Example format for reporting inherent availability (A_i). Hypothetical data show both total test and mature system data (see phase of test considerations).

	TOTAL TEST	MATURE SYSTEM	THRESH-OLD	STAN-DARD	GOAL
A_s1	87%	91%	85%	90%	96%
A_s2	86%	90%	85%	90%	95%

Figure 2-13. Example format for reporting scheduling availability (A_s). Hypothetical data show both total test and mature system values (see phase of test considerations).

A_i vs. A_s Implications. There is a particular importance to the relationship between A_i and A_s: A_i should always be greater than A_s. The difference between these two availabilities provides an index of the availability decrement directly relatable to possible logistics and/or administrative problems. Thus, the magnitude of this difference can provide the user with an indication of the availability gain to be derived from improved logistics support, improved maintenance management, or more effective operations scheduling.

Mission Capable Rates

MCR assessments are based on data gathered from all periods of operational mission testing. During these periods, the DLE records all clockhours that the simulator is "possessed"[1] plus clockhours that the simulator is fully mission capable, partially mission capable, or nonmission capable. The DLE uses a mission capable chart to collect the necessary data. This chart provides a chronological accounting of the status of the device, with regard to its capability to support its intended mission. (See Appendix C for a sample mission capable chart and guidelines for its completion.)

Full mission capable (FMC) is defined in AFR 65-110[2] as the percentage of possessed time that a system is capable of performing all of its assigned mission. A discrepancy which does not detract from or degrade mission capability is not reflected as non-FMC time.

Non-FMC time is divided into two categories in accord with AFR 65-110, depending on its mission impact. The two major categories are: not mission capable (NMC) and partial mission capable (PMC). These two categories are further classified as follows:

- NMCM scheduled: This status occurs whenever the simulator is undergoing inspections or preventive maintenance and the simulator is not usable for mission accomplishment. Daily inspection, such as pre- and post-mission checks, will not be counted as NMCM scheduled time. (These checks are FMC functions.)

- NMCM unscheduled: This status occurs whenever the simulator requires unscheduled maintenance which must be accomplished before any further operational training can be accomplished.

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[1] "Possessed time" is defined as the time from initiation of mission testing until its completion. If the simulator stops operating for any reason other than for maintenance or supply, that time will not be included.

[2] AFR 65-110, "Standard Aerospace Vehicle and Equipment Inventory, Status, and Utilization Reporting."

- NMCS: This status occurs whenever the simulator is not capable of performing any operational missions because of a lack of parts. For the purposes of this objective, NMCS time under 0.5 hours will normally be reported as NMCM unscheduled if the required part is obtained within that 0.5 hours (NMCS status begins at the time the part is determined to be non-available and that no further maintenance can be accomplished). If the required part is obtained within 0.5 hours, the simulator will be considered NMCS from the time the part was required and maintenance ceased.

- PMCM. This status occurs when the simulator can be used for operational training but it cannot perform all required missions because of one or more systems or subsystems being inoperative. Additionally, maintenance must be in progress or deferred for reasons other than lack of parts or supplies. Daily or local inspections will count as PMCM.

- PMCS. This status occurs when the simulator can be used for operational training but it cannot perform all required missions because of a lack of parts. The same criteria as described in the NMCS paragraph apply here.

- Flyable. This is the sum of the PMCS, PMCM, and FMC times.

Using the data on clockhours per type of status, and the possessed clockhours data, the DLE calculates the mission capable rates using the computational formulas contained in Appendix C. The DLE then analyzes the cause of less than desired PMC/NMC rates and determines what, if any, specific subsystems/components are driving these rates. For rates which fall below threshold value, the DLE determines the primary causes and then examines the basic reliability and maintainability data to obtain additional material for possible submittal of a service report. Service reports may be submitted against specific components if it is possible to determine which components are consistently causing the PMC/NMC rate.

The DLE ensures that the status chart is updated daily. Additionally, he provides the test director the overall system availability figures for inclusion in the final OT&E test report using an appropriate reporting table. The DLE also includes an evaluation of work unit code versus PMC/NMC rates in the final report. An example of MCR final report table is shown in Figure 2-14.

	TOTAL TEST	MATURE SYSTEM	THRESH-OLD	STAN-DARD	GOAL
NMCM scheduled	1.2%	1.2%	4.0%	1.5%	1.2%
NMCM unscheduled	7.2%	1.6%	9.6%	2.5%	2.0%
NMCM (total)	8.4%	2.8%	13.6%	4.0%	3.2%
NMCS	1.9%	0.0%	3.0%	1.0%	0.8%
PMCM	16.4%	23.2%			
PMCS	46.3%	32.6%			
FMC	26.9%	41.4%			
Flyable total (PMCM+PMCS+FMC)	89.6%	97.2%	83.0%	95.0%	96.0%

Figure 2-14. Example format for reporting mission capable rates (MCR). Hypothetical data show both total test and mature system values (see phase of test considerations).

D. LOGISTICS SUPPORTABILITY

LOGISTICS SUPPORTABILITY EVALUATION ELEMENTS

Logistics supportability concerns those areas having to do with supporting/maintaining the prime system equipment in its intended operating environment. In ATD OT&E it is critical to evaluate the adequacy of all logistics support elements in order to identify those areas of concern relative to the support of the system throughout its programmed life-cycle. The consequences of improper attention to system logistics needs can be costly delays in operational maintenance and even costlier delays and/or interruptions to the ongoing training of aircrew personnel.

LOGISTICS SUPPORTABILITY EVALUATION METHODS

The procedures for addressing logistics supportability concerns are not currently as well defined as are those for reliability, maintainability, and availability. Logistics supportability evaluations during ATD OT&E are mostly qualitative in nature and are, therefore, highly dependent on the expertise and experience of the responsible DLE team personnel. As a consequence, the results of such evaluations often cannot readily be subjected to rigorous threshold accept/reject criteria.

The factors examined during logistics supportability evaluations include the following: Personnel; Support Equipment; Supply Support; Training; Technical Data; Facility; Transportation and Handling; and Depot Supportability (as applicable). Evaluation of these factors is discussed below.

Personnel

The purpose of examining personnel requirements factors during ATD OT&E is to validate and update the accuracy of earlier manpower planning estimates (both numbers and skill levels). Of interest are the personnel required for the maintenance of the ATD and its associated support equipment throughout its programmed life-cycle. Evaluation of manpower requirements is conducted to determine whether they are adequate to meet the requirements specified for the ATD by the MAJCOM operational concept. The DLE's assessments during OT&E are compared with the contractor's maintenance manning proposal and the proposed unit manning requirements (UMR) to identify any needed modifications.

There are two basic meth[illegible] to estimate manpower requirements. The primary method [illegible] all systems is described in AFM

26-3, "Air Force Manpower Standards." This manual is usually supplemented by additional guidance from using commands to cover command-unique manpower standards. The second method is the logistics composite model (LCOM). Although the LCOM is the preferred method for performing manpower analyses and assessments for aircraft systems, AFM 26-3 procedures are customarily used for ATDs. AFM 26-3 provides criteria and equations for calculating manpower requirements for virtually every organizational element authorized in any Air Force unit and also provides rules appropriate for ATD operations where special manning requirements exist.

Manpower requirements evaluations include both direct and indirect manning needs by position and shift. For ATDs, operations and maintenance manpower is based on "position manning requirements," because one or more maintenance personnel must always be present in the operations or maintenance areas regardless of the productive time expended. This changes to a requirement that two or more people be present whenever simulator power is applied (one of these personnel must be a Training Devices Technician [AFSC 3417X] qualified in system operation). The minimum numbers of people required per position or shift, and per month, are usually calculated by the DLE team manpower specialist as described in Appendix D.

Evaluations of personnel requirements during OT&E serve two purposes. They provide a basis for (a) validating cost estimates, and (b) for finalizing the device operations and maintenance manpower requirements.

ATD Support Equipment

ATD support equipment (SE) consists of all special tools, monitoring and checkout equipment, measurement and calibration equipment, maintenance stands, and handling equipment required to support scheduled and unscheduled maintenance actions associated with the prime equipment. SE is considered "standard" if it is off-the-shelf and/or already nationally stocklisted. It is considered "ATD peculiar" if it is newly designed and unique to the ATD being evaluated. The procedures, definitions, and criteria described earlier in ATD reliability and maintainability determinations are also used for comparable SE evaluations. The DLE usually uses the same data gathering instruments (e.g., AFTO 349) for SE suitability assessments as were used during reliability/maintainability evaluations. He may also employ a special SE evaluation checklist for the compilation of qualitative SE information. An example of such a checklist is provided in Appendix D.

Supply Support

Supply support (Spares and Repair Parts) consists of all repairable and nonrepairable spares (units, assemblies, modules, etc.), repair parts, consumables, special supplies, and related inventories needed to support scheduled and unscheduled maintenance actions associated with the prime equipment, test and support equipment, facilities, and training equipment. Supply support considerations address each maintenance level (echelon) and each geographical location where spare/repair parts are distributed and stocked, the distances between stockage points, and the methods of material distribution. The purpose of evaluating supply support is to anticipate, insofar as possible, utilization problems which may be encountered due to supply shortages. A number of data sources are available for the assessment of ATD supply support. These data sources include supply consumption data, condemnation events and duration of status, projected support requirements (provisioning), proposed bench stock, LSA (logistics support analysis) reports, availability (NCS) rates, packaging and handling information, and service reports (SRs).

The DLE logistics specialist and supply analyst review and evaluate stock usage during OT&E to determine adequacy, completeness, and/or deficiencies in the contractor's proposed spares provisioning. LSA reports also are reviewed and compared to actual failure data. The DLE determines whether the contractor's stockage level for the device is acceptable.

If the test is being conducted under the standard Air Force maintenance data collection (MDC) system, e.g., AFTO 349, then available data are used to compute actual spares consumption, not-repairable-this-station rates (NRTS), depot overhaul turnaround times, mean-time-between-demand rates (MTBD), condemnation rates, and cannibalization rates. These rates allow the DLE logistics specialist to recommend adjustments in spare parts levels to compensate for actual high and/or very low usage rate items. Note that the MDC system requires that detailed work unit codes are available at the beginning of test.

The adequacy of packaging and handling procedures and materials is determined subjectively. Reports are submitted on an exception basis whenever improper packaging and handling procedures or material are discovered.

Training

In addition to personnel requirement determinations, the adequacy of maintenance training plans and programs must be assessed. To accomplish this evaluation, which by necessity is largely subjective in nature, the DLE, with the assistance of ATC training specialists, reviews the planned training to determine areas of potential problems. This review of training plans and proposed course oulines is accomplished by the DLE training specialist, and any observed training inadequacies are reported to the OT&E test director. The results of this training evaluation may modify subsequent ATC course content, OJT procedures, training aids, and associated training methods.

Technical Data

Technical data are the TOs, drawings, microfilm, operating and maintenance instructions, modification instructions, provisioning and facilities information, specifications, inspection and calibration procedures, and computer programs required to support installation, checkout, operation, and maintenance of the prime equipment and associated test and support equipment.

DLE technical data specialists/simulator technicians conduct preliminary evaluations of technical data during TO reviews, the maintainability demonstration, and during whatever other times the appropriate technical data are available. All utilized technical data, including contractor drawings, are evaluated for suitability, adequacy, completeness, and correctness. The evaluations provide identification of unsatisfactory maintenance procedures in technical data; identification of inconsistencies with general hardware TOs; assurance that all safety requirements are included in the handbooks and that warning and caution notes have been incorporated; assurance that the -6 handbook reflects repair restrictions and time-change requirements; and analysis of bench-check-serviceable rates and could-not-duplicate rates to identify those occurrences caused or encouraged by poor technical data.

The availability of technical data (or lack thereof) during early OT&E phases sometimes poses a problem. In some cases, evaluation of technical data may have to be postponed until sufficient such data are available.

An in-depth comprehensive analysis of technical data during ATD OT&E often is not possible since a complete set of verified and validated technical data will not normally be available for review. The use of overly detailed procedures for evaluation of technical data is therefore usually inappropriate during ATD IOT&E. Even the evaluation checklists included in Appendix D may be too extensive for use with early technical data and may necessitate an approach wherein only glaring discrepancies can be noted.

Deficiencies in preliminary technical publications are identified using AFTO Form 158. The DLE technical data specialist will ensure that copies of AFTO Form 158 and supporting review comments are made available for this evaluation. Normally, a more comprehensive technical data review is possible during FOT&E subsequent to verification and validation. In this case, AFTO Form 22 is used instead of Form 158 to record comments and deficiencies.

To aid in analysis and evaluation of pertinent technical data, checklists can be employed that address manual content and style. Examples of technical data evaluation checklists are contained in Appendix D.

Facilities

Facilities consist of the physical plant, real estate, portable buildings, housing, intermediate shops, depots, etc., required to support the operational and maintenance functions associated with the ATD, its test and support equipment, training equipment required throughout the ATD's life-cycle, storage for spare/repair parts and data, administrative space for operator maintenance personnel, and training operations areas.

The adequacy of ATD support facilities is an area of OT&E assessment that depends largely on subjective judgments. The expertise and experience of the responsible DLE personnel therefore greatly affect the outcomes of the evaluation. All maintenance activities should be monitored to identify any facilities requirements that are not adequately met. DLE personnel should review applicable publications and maintenance and SE requirements, and report any required new facilities, additions, or modifications deemed necessary to support the ATD. Support can also be solicited from other responsible agencies, including the maintenance contractor, SimSPO, MAJCOM, and ATC, in accomplishing this evaluation.

The DLE facilities specialist customarily evaluates the facilities using a facilities evaluation checklist. Problem areas are reported on an exception basis; i.e., if a problem or potential problem is identified, it is reported using the SR/ID reporting system. Quantitative data are kept on those facility-related systems which are integral to the simulator, regardless of whether these systems are managed as equipment or real property.

The facilities evaluation usually encompasses a thorough subjective evaluation of the maintenance work areas, classroom training areas, briefing/debriefing areas, storage areas, supervision areas, computer areas, hydraulic pump room (motion-based ATDs), simulator bay, computer bay, instructor-operator station, etc., using a checklist that allows, as a minimum, evaluation of the adequacy of the following:

(1) Space

(2) Electrical power systems

(3) Lighting

(4) Cooling systems

(5) Simulator clearances

(6) Convenience factors

(7) Emergency exits

(8) Quality of materials used

(9) Human factors (related to facilities)

(10) Storage requirements

(11) Built-in support equipment

(12) Fire extinguishing/suppression systems

(13) External ingress/egress

(14) Security (physical and classification)

The DLE analyzes and evaluates the facilities evaluation checklists completed by the various evaluators for their area of interest. The DLE may initiate service reports at any time a facilities problem is detected. The DLE summarizes facilities problems in interim and final reports to the test director. A typical facilities evaluation checklist is provided in Appendix D.

Transportation and Handling

Transportation and handling addresses those special provisions such as reusable containers and supplies necessary to support packaging, preservation, storage, handling, and/or transportation of prime equipment, test and support equipment, spare/repair parts, technical data, and facilities.

Logistics evaluation personnel observe contractor transportation and handling of the ATD equipment and supplies. Additionally, the transportation design characteristics of all major components are reviewed. As problems or potential problems are detected, they are reported by the SR process to the DLE. The transportation and handling checklist is completed for the transport of the simulator/systems, and checklists will be completed on a sampling of various supplies. All findings are included in the final OT&E report. An example of a transportation and handling checklist is shown in Appendix D.

Mil standard transportation and handling evaluations during ATD OT&E may not be possible to accomplish if military standard transportation and handling requirements are waived, for example, allowing the contractor to use "best commercial practice" procedures. Such a waiver is a common occurrence.

Depot Supportability (as applicable)

Depot supportability is concerned with the projected workload, the skills and manpower required for repair, facility requirements, tools and test equipment, software, data, training, and spare parts required to develop an organic depot overhaul capability.

A number of data sources may be utilized in evaluation of depot supportability. These include the depot facility site survey, technical data and drawings, repairable item lists, automated test equipment, software documentation, training plan/course identification, service reports, logistics support analysis (LSA reports), firmware documentation DIDs (Data Item Descriptions), and tools and test equipment (both peculiar and common).

An experienced simulator logistics specialist is required for the evaluation of depot supportability, because relevant data must be considered subjectively. Findings in this area are compiled into a depot maintenance capability development plan by the DLE and provided to the test director for incorporation into the final report.

LOGISTICS SUPPORTABILITY: TEST DIRECTOR CONCERNS

Phase of Test Considerations

Logistics supportability assessments provide insight into other suitability factors and impact a number of critical decision areas. The most apparent of these has to do with the planning and budgeting for downstream life-cycle costs. Another key area concerns the logistics support complement of future devices of the same or similar type and application. For example, support equipment may have been specified for the device under test that is not really needed, and conversely, necessary SE may have been omitted. This finding could be used to define future system support packages.

Personnel Requirements

Logisitics supportability assessments ordinarily will be carried out by delegating such responsibilities to available simulator technicians. However, contact by the test director with expert personnel in the following identified areas of interest is strongly recommended during early test planning and for review both of planned test procedures and the logistics supportability portion of the final report. In this way, these personnel need only be accessed for comparatively brief periods during conduct of the test. Accessing these two specialists is of particular importance.

	SOURCE	AFSC	NUMBER
Simulator Technician	AFLC	3417X*	2
Supply Systems Specialist	AFLC	64552	1
Manpower Management Officer	MAJCOM	7424	1
Supply Operations Officer	MAJCOM	6424	1
Training Technician	MAJCOM/ATC	75172	1
Transportation Officer	AFLC	6054	1
Civil Engineering Officer	OOALC/MAJCOM	5516	1
Packaging Specialist	AFLC	60252	1

*"X" Specialty area as appropriate to device under evaluation.

E. OPERATING AND SUPPORT COSTS

O&S COST EVALUATION ELEMENTS

Six major elements of ATD O&S costs should be considered during OT&E. These are: (1) simulator maintenance manpower, (2) replenishment spares, (3) simulator maintenance materiel, (4) support equipment, (5) facility maintenance costs, and (6) electrical power costs.

Simulator Maintenance Manpower

This cost element refers to the cost of manpower required to maintain the simulator in its intended operational environment. This element is basically the cost of providing those personnel needed to meet the base-level maintenance requirements of the simulator. This element includes all manpower costs incurred to meet the direct maintenance demands of the simulator, to provide for maintenance supervision, and to cover administrative requirements such as leave, sickness, TDY, etc. Included are personnel at both the organization and intermediate levels. Not included, however, are depot level maintenance personnel who may be required periodically at centralized depot repair facilities. If contractor field service support (CFS) and/or field service representatives (FSR) are required, such costs are also incorporated.

Replenishment Spares

This element covers the cost of procuring system assemblies, spares, and repairable parts which are normally repaired and returned to stock. In addition, it includes procurement of stock levels that are not provided by initial spares procurement. These are centrally managed investment type items.

Simulator Maintenance Materiel

This element is the cost of purchasing materiel from the general and system support division of the stock fund. This includes all nonrepairable expense-type items including bench stock, direct materiel, and base operating consumables used in the organizational and intermediate maintenance activities at base level.

Support Equipment

This element covers the cost of procuring common maintenance and repair shop equipment, instruments, test equipment, and spares for this equipment. These equipment demands are generated by a need to (1) replace peculiar support equipment bought using system procurement funds, (2) obtain common, off-the-shelf support equipment that is needed to support operations as production systems in the operating inventory, and (3) provide replenishment of common equipment that is no longer repairable.

Simulator Facility

This cost element includes all direct labor, materiel overhead, and other direct charges incurred in maintenance of the simulator facility (it includes maintenance of real property where applicable).

Electrical Power

This cost element reflects the annual cost of batt[illegible], generator, and commercially supplied power for the operation of the simulator.

O&S COSTS: TEST DIRECTOR CONCERNS

Phase of Test Considerations

A cost analyst should be involved in early planning meetings to identify the specific cost-related data it will be necessary to track during test. At this point, the analyst may be needed only for a few weeks. As the test proceeds, the relevant data are made available to the cost analyst who will effect the necessary cost calculations and provide the appropriate reports to the DLE.

A number of factors will affect O&S cost estimates. Supportability factors are of particular impact, for example. If the supporting technical data are inadequate, the skill levels of technical personnel will have to be increased to compensate for that inadequacy. On the other hand, if the technical data are of high quality, lower skill level personnel can be utilized, thus decreasing the support costs for ATD personnel.

Initial O&S cost estimates from early OT&E phases can be used to develop inputs to the using command's O&M budget. Also, such O&S cost data can be used to support a source selection decision. For example, should the cost of electrical power to run device A be substantially greater than that required to run device B, then, with other factors being equal, a decision to buy device B could be justified.

Personnel Requirements

As noted above, a cost analyst is needed to specify needed information early on, and to perform the necessary analyses after those data are collected.

SPECIALTY	SOURCE	AFSC	NUMBER
Cost Analyst	MAJCOM	6746	1

CHAPTER 3

SOFTWARE SUITABILITY

INTRODUCTION

Modern ATDs have a substantial software component. Software controlled elements of ATDs normally provide the "flying" characteristics of the device via programmed aerodynamic models, as well as the operating characteristics of navigational, weapons, ECM, and communications systems, among others. In addition, ATD training support features (freeze, record/replay, etc.) are controlled largely by software.

The extensive role of software in ATD system operation creates a substantial need for its critical evaluation during OT&E. The procedures for that evaluation are quite different from those appropriate for hardware suitability assessments, however, because there are distinct differences between hardware and software failure effects which must be recognized. Software evaluation procedures must reflect those differences.

Important to understanding the concepts of hardware/software testing during ATD OT&E is a knowledge of the difference between hardware and software failure effects. Hardware failures are almost always the result of component damage or deterioration due to age, humidity, temperature, vibration, etc. Hardware failures will recur. Software "failures" arise only from program design and/or implementation errors. Software does not fail or degrade over time. The occurrence of a system failure due to a software failure may be similar, in net effect, to a hardware failure. However, once the software has been corrected, it will never "fail" in the same way again. As a consequence, the concepts, measures, and techniques appropriate for hardware suitability evaluation cannot be used directly to test software.

RESPONSIBILITIES OF SOFTWARE EVALUATION PERSONNEL

Deputy for Software Evaluation

The focal point for all software evaluation matters is the Deputy for Software Evaluation (DSE). Specifically, the DSE:

(a) Manages the software evaluators. This includes planning, scheduling, and coordinating evaluation activities and assigning evaluators to perform required tasks.

(b) Establishes any unique procedures required for effective control of software related activities.

(c) Coordinates software activities with other test activities and refers potential schedule or resource conflicts to the OT&E test director for resolution.

(d) Prepares and submits status reports, as required, to the test director.

(e) Participates in the software configuration control process. Maintains cognizance of all software changes proposed and in various stages of implementation. Chairs a software problem review board during OT&E.

Software Evaluators and Analysts

Under the guidance of the DSE, the evaluators are responsible for making a unified assessment of the software. The specific responsibilities of these software evaluation personnel supporting the OT&E are:

(a) Assist the DSE in selecting software documentation and source listing to be evaluated.

(b) Assist the DSE in preparation of the software assessment portions of the final report.

(c) Assist the DSE in administering the Software Operator-Machine Interface Questionnaires.

(d) Collect, monitor, and review data for computer support resources and all software objectives.

(e) Identify software discrepancies and monitor corrective actions.

(f) Complete software documentation and software source listing questionnaires, and operator-interface questionnaires.

(g) Prepare Computer Program Observation Reports (AFTEC Form 207) to document anomalies or problems noted during software suitability evaluation.

AFTEC ATD SOFTWARE EVALUATION APPROACH

As noted in the first chapter of this volume, software evaluation guidelines have been provided in the five-volume AFTEC Handbook, "Software OT&E Guidelines." AFTEC software OT&E concerns and associated evaluation techniques continue to evolve, however, and no set of methods has been developed to date which applies to all systems and all OT&Es. Therefore, the intent of the AFTEC handbook[1] is not directive, but rather is that of providing a source of information and guidelines regarding software OT&E.

The AFTEC approach to software evaluation documented in that handbook distinguishes between "software suitability," which is concerned with maintainability and usability of software, and "software effectiveness," which is concerned with the performance of the software from the standpoint of system operational effectiveness. The current AFTEC approach to software effectiveness per se considers it to be part of the total ATD operational effectiveness evaluation. As a result, separately defined evaluation procedures for sofware effectiveness have not been developed. However, for ATD software suitability, AFTEC has developed an approach based largely on the use of subjective questionnaires.

This chapter, therefore, is primarily directed to the topic of ATD software suitability evaluation, as prescribed by AFTEC's current software evaluation handbook. Definitions for the major elements of software suitability are provided, as are generic personnel requirements and special concerns of the test director relative to software evaluation during ATD OT&E.

Elements of Software Suitability

Operational suitability evaluation for software will typically address the overall concerns of software maintainability and software usability. Under these two categories, a number of subelements are considered as shown in Figure 3-1.

Each of these two major elements is defined more fully in the following subsections: A. Software Maintainability; and B. Software Usability.[2]

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[1] Inasmuch as software evaluation techniques remain an evolving process, the test director should be certain to access the most recent editions of that handbook available to him.

[2] The intent here is to acquaint the new test director with the basic philosophy of software suitability evaluations as currently developed at AFTEC. Therefore, much of the material in these sections has been excerpted directly from the AFTEC handbooks noted above.

MAINTAINABILITY	USABILITY
DOCUMENTATION	OPERATOR-MACHINE INTERFACE
Modularity	Descriptiveness
Descriptiveness	Consistency
Consistency	Simplicity
Simplicity	Assurability
Expandability	Controllability
Instrumentation	Workload Reasonability
SOURCE LISTINGS	FUNCTIONAL PERFORMANCE
Modularity	Failures
Descriptiveness	
Consistency	
Simplicity	
Expandability	
Instrumentation	

Figure 3-1. Subelements of software maintainability and usability.

A. SOFTWARE MAINTAINABILITY

Software consists of a set of computer instructions and data structured into programs, and the associated documentation on the design, implementation, test, support, and operation of those programs. Each software program is separately evaluated and consists of a set of components called modules. A module may, in general, be at any conceptual level of the program. In FORTRAN, modules are generally defined to be subroutines; in COBOL, a module is usually a total program. The DSE must decide on the definition of a module for the specific language and system to be evaluated.

SOFTWARE MAINTAINABILITY EVALUATION ELEMENTS

In the course of using an ATD, as well as during its OT&E, it may become necessary to maintain or change its software. Such software changes are made to: (a) correct errors, (b) add system capabilities, (c) delete features from programs, or (d) modify software to be compatible with hardware changes. The maintainability of the software is a function of those characteristics of the software and its computer support resources which affect the ability of software programmer/analysts to make such changes.

The AFTEC methodology for evaluating software maintainability is based on the use of closed form questionnaires with optional written comments. These questionnaires are designed to determine the presence or absence of certain desirable attributes in a given software product. The elements of software maintainability and their relationships, as shown in Figure 3-1, are described in following paragraphs. The hierarchical evaluation structure shown in the figure enables the identification of potential maintainability problems at various levels: category (documentation, source listings), characteristic (modularity, consistency, etc.). For each software program there are two related categories that are evaluated for characteristics which affect software maintainability. These are (1) software documentation, and (2) software source listings. A third category, computer support resources, is also appropriate for such evaluation. This category includes all the relevant resources such as auxiliary software, computer equipment, facilities, etc., which will be used to support the maintenance of the software being evaluated. However, procedures for the evaluation of computer support resources are currently under development by AFTEC and therefore cannot be further addressed in this present Handbook.

Software Documentation

Software program documentation is the set of requirements, design specifications, guidelines, operational procedures, test information, problem reports, etc. which in total form comprise the written description of a computer program. The primary documentation used in this evaluation consists of the documents containing program design specifications, program testing information and procedures, and program maintenance information. These documents may have a variety of configurations depending upon the particular application. The documents are evaluated both for content and for general physical structure (format). The content evaluation is primarily concerned with how well the overall program has been designed (as documented) for maintainability. The format evaluation is primarily aimed at how the physical structure of the documentation (table of contents, index, numbering schemes, modular separation of parts, etc.) aids in understanding or locating program information.

Software Source Listings

Software source listings are the computer generated (or equivalent) form of the program code in its source language (e.g., FORTRAN, COBOL, JOVIAL, AdA, assembly language, etc.). The source listing represents the program as implemented, in contrast to the documentation which for the most part represents the program design or implementation plan. In essence, source listings are also considered a form of program documentation, but for maintainability evaluation, a distinction is made.

The source listing evaluation consists of a separate evaluation of each selected module's source listing and the consistency between the module's source listing and the related module documentation. The separate module evaluations are summarized to yield an overall evaluation of the software source listing for the given program.

Software Maintainability Subelements

The maintainability of software documentation and source listings is determined by examining six subelements: modularity, descriptiveness, consistency, simplicity, expandability, and instrumentation. Discussions of these subelements and their application in the evaluation of the software documentation and source listings are provided below.

Modularity. Software possesses the characteristic of modularity to the extent that a logical partitioning of software into parts, components, and/or modules has occurred. Software that is the easiest to understand and change is composed of independent modules. Each software product is therefore evaluated in relation to the extent to which its logical parts, components, and modules are independent. The fewer and simpler the connections between parts, the easier it is to understand each module without reference to other parts. Minimizing connections between parts also minimizes the paths along which changes and errors can propagate into other parts of the system, thus reducing the occurrence of side effects within the system.

As a general guideline, modularity implies that a given module consists of only a few easily recognizable functions which are closely related and that a minimal number of links exist to other modules--preferably only via parameters passed in a calling parameter list. In addition, the physical format of the documentation should exhibit component independence for its sections, volumes, etc. There should be separate sections for the description of the major parts which a given document's purpose encompasses.

Descriptiveness. Software possesses the characteristic of descriptiveness to the extent that it contains information regarding its objectives, assumptions, inputs, processing, outputs, components, revision status, etc. This attribute is very important in understanding software. Documentation should have a descriptive format and contain useful explanations of the software program design. The objectives, assumptions, inputs, etc., are useful (in varying degrees of detail) in both documentation and source listings. In addition, the descriptiveness of the source language syntax and the judicious use of source commentary greatly aids efforts to understand the program operation.

Consistency. Software possesses the characteristic of consistency to the extent the software products correlate and contain uniform notation, terminology and symbology. The use of standards in documentation, flow chart construction and certain conventions in I/O processing, error processing, module interfacing, naming of modules/variables, etc. are typical reflections of consistency. Attention to consistency characteristics can greatly aid one in understanding the program. Consistency allows one to generalize easily. For example, programs using consistent conventions require that the format of modules be similar. Thus, by learning the format of one module (preface block, declaration format, error checks, etc.), the format of all modules is learned. This allows one to concentrate on understanding the true complexities of an algorithm, data structure, etc.

Simplicity. Software possesses the characteristic of simplicity to the extent that it lacks complexity in organization, language, and implementation techniques, and to the extent that it reflects the use of singularity concepts and fundamental structures. The aspects of software complexity (or lack of simplicity) that are emphasized in the evaluation relate primarily to the concepts of size and primitives. The less there is to discriminate and the more use there is of basic or primitive techniques, structures, etc., the simpler the software will tend to be. The use of a high order language as opposed to an assembly language tends to make a program simpler to understand, because there are fewer discriminations which have to be made. There are certain programming considerations such as dynamic allocation of resources and recursive/reentrant coding which can greatly complicate the data and control flow. Real-time programs, because of the requirement for timing constraints and efficiency, tend to have more control complexity.

The sheer bulk of a module (number of operators, operands, nested control structures, nested data structures, executable statements, statement labels, decision parameters, etc.) will determine to a great extent how simple or complex the source code is. While it is recognized that the particular application itself may preclude the possibility of a reasonably simple design or implementation, because of requirements such as a particularly complex real-time scheduling algorithm or high level mathematical or other theoretical considerations, this complexity nonetheless makes maintenance more difficult.

Expandability. Software possesses the characteristic of expandability to the extent that a physical change to information, computational functions, data storage, or execution time can be easily accomplished once the nature of what is to be changed is understood.

Software may be perfectly understandable, but not easily expandable. If the design of the program has not allowed for a flexible timing scheme or a reasonable storage margin, then even minor changes may be extremely difficult to implement. Parameterization of constants and basic data structure sizes usually improves expandability. It is also very important that the documentation include explanations of how to effect increases/decreases in data structure sizes or changes to the timing scheme, and the limitations of such program expandability should be clear. The numbering schemes for source listings, documentation narrative, and graphic materials must be carefully considered so that physical modifications to the code and documentation can be easily accomplished when necessary.

Instrumentation. Software possesses the characteristic of instrumentation to the extent that it contains aids which enhance testing. For the most part, the documentation is evaluated on how well the program has been designed to include test aids (instruments), while the source listings are evaluated on how well the code seems to be implemented to allow for testing through the use of such test aids. This part of the evaluation reflects the concern (from a maintainability viewpoint) that the software be designed and implemented so that instrumentation is either imbedded within the program, can be easily inserted into the program, is available through a support software system, or is available through a combination of these capabilities.

SOFTWARE MAINTAINABILITY EVALUATION METHODS

The basic software maintainability evaluation procedure involves four distinct phases: planning, calibration, assessment, and analysis.

During the planning phase, the test manager and the Deputy for Software Evaluation (DSE) establish an evaluator team consisting of at least five evaluators knowledgeable in software maintenance. The program/module hierarchy is established, and a set of representative modules is selected for each program to be evaluated. The schedule for the evaluation is also established at this time. The DSE briefs the evaluator team on the procedures and assigns the necessary identification information for this specific evaluation.

The function of the calibration phase is to assure a reliable evaluation by assuring that each evaluator has a clear understanding of the questions on each questionnaire and their specific response guidelines. Each evaluator completes a documentation and a module source listing questionnaire in a trial or calibration evaluation. The completed questionnaires are reviewed to detect areas of misunderstanding and the evaluation teams are debriefed on the problem areas.

In the assessment phase, the evaluation teams update their calibration test questionnaires based on the results of the calibration debriefing. The teams then complete the remainder of their assigned documentation and module source listing questionnaires.

In the analysis phase, the DSE accomplishes the conversion and initial data processing of the questionnaire data. The statistical summaries are then returned to the test director for detailed evaluation and preparation of the final report.

Data Collection Procedures (Questionnaires)

The questionnaires used for assessing the software documentation and source listings require rating responses following the rating scale shown below:

A. Completely Agree (absolutely no doubt)

B. Strongly Agree

C. Generally Agree

D. Generally Disagree

E. Strongly Disagree

F. Completely Disagree (absolutely no doubt)

In addition to a rating response, the individual evaluators may elect to submit a written comment.

Software documentation questionnaire. This questionnaire is used to evaluate the overall format and the content of the documentation (not including source listings) for the computer program being evaluated. Although the information required to answer the Software Documentation Questionnaire may be spread out among several distinct documents, the primary information sources which are always considered a part of the evaluation are the program functional/detailed design specifications and the program maintenance/operational procedures. Contractor programming conventions should also be made available. The documentation which is to be evaluated should be specified to the evaluator by the DSE prior to the calibration test. Appendix F contains the list of statements in this questionnaire.

Module source listing questionnaire. This questionnaire is used to evaluate the overall format and content of the source listing for the program module being evaluated, and to evaluate the consistency between the module's documentation and source listing. The program modules which are to be evaluated are specified to the evaluator prior to the calibration test. Appendix F contains the list of statements in this questionnaire.

Formatting of results. Once all data are gathered, they are weighted as specified in the AFTEC handbook, and average values are calculated. At this point the data should be formatted for easy interpretation of results. A particularly effective means for this is with bar graphs. Figure 3-2 shows an example of source listing results (as excerpted from the SAC air refueling part-task trainer IOT&E).[1]

SOFTWARE EVALUATION: TEST DIRECTOR CONCERNS

Phase of Test Considerations

One of the most important phases of test considerations relative to software is configuration management. This is because a large portion of software evaluation requires an accurate correlation between descriptive information (documentation/source listings) and the program, as it exists functionally, in order to facilitate post-delivery life-cycle support by software support personnel. Detailed requirements for software configuration management are contained in MIL-STD-1644(TD), "Military Standard for Trainer System Software Development."

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[1] Lambert, A. G., Jr., Amisano, R. P., Burch, N. T., & Zimick, D. C. Initial operational test and evaluation B-52 air refueling part task trainer (SAC Project 77-SAC-333). Castle AFB, CA: 4200 TES, July 1980.

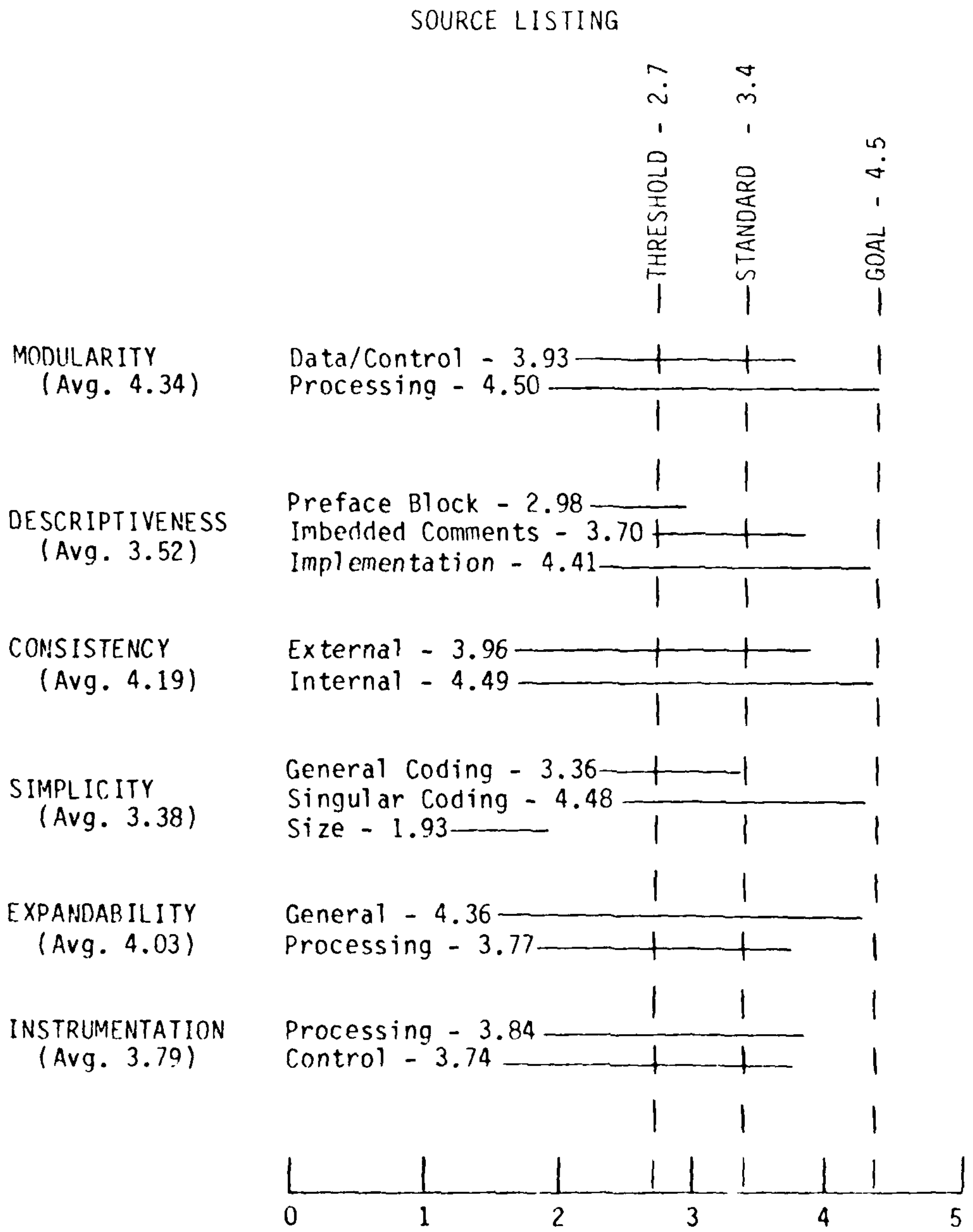

Figure 3-2. Example format for source listing results.

A related concern has to do with the high probability that the software as first implemented will need to be changed and updated to reflect changes in aircraft parameters, tactics, doctrine, and any other areas which impact task performance in the device. Often these changes require expeditious implementation, thereby requiring that the simulator system software be designed to facilitate efficient change over its life cycle. It is important to note that future software modifications will have to be implemented by personnel not associated with the original development effort.

There are two planning documents of particular importance with regard to software test and evaluation. These documents, which should be available to the test director, are the CRISP (Computer Resources Integrated Support Plan) and the O/S CMP (Operational/Support Configuration Management Procedures). These documents are intended to define what will be needed downstream to support the computer system and to maintain accurate configuration management for the system. AFLC regulation 800-21, "Management and Support Procedure for Computer Resources Used in Defense Systems," also contains useful information which may help to define terms and guide the software evaluator to additional sources of information.

Personnel Requirements

As is the case with many other areas of evaluation, personnel requirements will vary depending on system complexity. This applies even more so to the software area. One way to determine personnel requirements is to select a good DSE (Deputy for Software Evaluation) and give that individual the responsibility to define what is needed. Certain of the characteristics and considerations of a good DSE have been identified in the AFTEC handbook. These are excerpted below:

(a) The deputy for software evaluation (DSE) should be brought on board early to assist in detailed software OT&E planning and to become familiar with the system.

(b) It is imperative that the software test manager and the DSE have a good working relationship with each other, the contractor, and the program manager.

(c) It is imperative that the DSE is a self-motivator. If not, test team motivation becomes a problem.

(d) The DSE must be dedicated to the test for the entire test period including final report writing.

(e) The DSE should be an AFTEC/MAJCOM resource of equal rank to the deputy for logistics and the deputy for operations.

B. SOFTWARE USABILITY

SOFTWARE USABILITY EVALUATION ELEMENTS

Software usability is defined as the extent to which software designated to perform a support function is effective in performing that function and is "usable" by the Air Force operator. This evaluation normally concentrates on an analysis of the adequacy and effectiveness of nonmission software (e.g., off-line diagnostics, ATE software) in terms of operator-machine interface and functional performance. These two areas are discussed further below.

Software Operator-Machine Interface

This evaluation element considers the adequacy of that part of software design/implementation which affects interaction between a computer-driven system and its operator. It is divided into six subelements of evaluation concern which address various areas. Each of these subelements is defined and discussed in the subsequent evaluation methods section.

Software Functional Performance

As a usability concern, software functional performance refers to its capability to carry out its intended purposes. At present, this area is not well defined in AFTEC's software evaluation handbook. However, the test director should consult AFTEC software specialists to determine the current status of developments relative to functional performance evaluation.

SOFTWARE USABILITY EVALUATION METHODS

The methodology for evaluating the software portions of the operator-machine interface is based on the use of a closed form questionnaire with optional written comments. This questionnaire is designed to determine the extent of the presence of certain desirable attributes in a given system. Appendix G contains a listing of these questionnaire statements.

The desirable attributes addressed by the questionnaire are divided into six subelements: assurability, controllability, workload reasonability, descriptiveness, consistency, and simplicity. A complete understanding of the definitions of these subelements is of prime importance to an accurate evaluation; thus, the evaluator should study these definitions carefully.

Assurability

A computerized system contains the quality of assurability to the extent that it aids the operator in validating data, avoiding errors, and correcting errors once made. A system which has been designed to aid the operator in error avoidance may or may not have good assurability. A system should also be designed so that errors are easy to correct and, above all, so that errors do not have catastrophic effects.

Controllability

A computerized system contains the quality of controllability to the extent that it allows the operator to direct the operations of the machine. The operator must be able to direct or control the operation of the machine in order to utilize it effectively and efficiently.

Workload Reasonability

A computerized system contains the quality of workload reasonability to the extent that the tasks required of the operator are within the operator's capability and require the operator to perform a useful, meaningful role. Optimum design of a system which involves an operator and a computerized machine takes advantage of the best capabilities of both: the machine to perform repetitive tasks rapidly, and the operator to make command decisions involving unusual situations.

Descriptiveness

A computerized system contains the quality of descriptiveness to the extent that the operator has available adequate explanations of every function the operator is required to perform and every function the machine performs. The operator need not be informed in detail of every task the machine performs, but there are certain things the operator must know to fulfill the mission. The questionnaire relies upon the knowledge of the operator to define what it is the operator needs to know.

Consistency

A computerized system contains the quality of consistency to the extent that the behavior of the machine and documentation correspond to the expectations of the operator. There should be a near one-to-one correspondence between what the machine does, what the documentation says it will do, and what the operator has been trained to expect the machine to do. Furthermore, the documentation normally available to the operator should agree with that which the operator has been trained to expect.

Simplicity

A computerized system contains the quality of simplicity to the extent that the information presented to the operator or entered by the operator is grouped into short, readily understandable structures. Complicated data structures, data entry formats, or operator manuals all require the operator to spend more time in developing an understanding of the system, and may have a tendency to confuse the operator as well.

The above identified subelements have been grouped logically by AFTEC into factors of "operability" and "communicativeness." A computerized system contains the quality of operability to the extent that the operator is in control of the operator-machine interface. Operability is the sum of assurability, controllability, and workload reasonability. A computerized system contains the quality of communicativeness to the extent that the transfer of information between the operator and the machine is concise and complete. Communicativeness is the sum of descriptiveness, consistency, and simplicity.

REFERENCES

1. Cunningham, C. E., & Cox, W. Applied maintainability engineering. New York: John Wiley & Sons, Inc., 1972.

2. Blanchard, B. S. Logistics engineering and management. Englewood Cliffs, NJ: Prentice-Hall, 1974.

3. Lambert, A. G., Jr., Amisano, R. P., Burch, N. T., & Zimick, D. C. Initial operational test and evaluation B-52 air refueling part task trainer (SAC Proj. 77-SAC-333). Castle AFB, CA: 4200 TES, July 1980.

4. VonAlven, W. H. (Ed.) Reliability engineering. Englewood Cliffs, NJ: Prentice-Hall, 1968.

5. AFR 65-110, "Standard Aerospace Vehicle and Equipment Inventory, Status, and Utilizing Reporting."

6. AFR 80-5, "Reliability and Maintainability Programs for Systems, Subsystems, Equipment, and Munitions."

7. AFR 80-14, "Test and Evaluation."

8. AFLCR 80-4, "Test and Evaluation."

9. AFLCR 800-21, "Management and Support Procedure for Computer Resources Used in Defense Systems."

10. AFM 26-3, "Air Force Manpower Standards."

11. AFM 55-43, "Management of Operational Test and Evaluation."

12. AFTECP 400-1, "Logistics Assessment."

13. AFTEC, "Software OT&E Guidelines." Kirtland AFB, NM: Air Force Test and Evaluation Center. Volumes in this handbook set include the following:

    I. Software Test Manager's Handbook (published February 1981)

    II. Handbook for Deputy for Software Evaluation (to be published)

    III. Software Maintainability Evaluator's Handbook (published April 1980)

IV. Software Operator-Machine Interface Evaluator's Handbook (published July 1980)

V. Computer Support Resources Evaluator's Handbook (to be published)

14. MIL-STD-470, "Maintainability Program Requirements."

15. MIL-STD-471, "Maintainability Verification/Demonstration/Evaluation."

16. MIL-STD-781, "Reliability Design Qualification and Production Acceptance Tests."

17. MIL-STD-1472, "Human Engineering Design Criteria for Military Systems, Equipment, and Facilities."

18. MIL-STD-1644 (TD), "Military Standard for Trainer Systems Software Development."

APPENDIX A

ADDITIONAL RELIABILITY INFORMATION

BITE RATE CODES

The following is a listing and definition of BITE Rate Codes used when collecting BITE Reliability Data.

Code	Definition
B1	BITE indicated a problem.
B200	BITE should have, but did not, indicate a problem.

(If code B1 is used, a third code character is required, as follows.)

B13	BITE isolated the problem to the required level.
B14	BITE did not isolate the problem to the required level.

(If codes B13 or B14 are used, a fourth code character is required.)

(For code B13:)

B135	BITE-indicated problem is confirmed.
B136	BITE-indicated problem is not confirmed, i.e., the "faulty" component was not, in fact, faulty (CND), but another component was faulty.
B137	BITE-indicated problem is not confirmed (CND), and there was no malfunction at all.

(For code B14:)

B148	BITE did not isolate the problem to the required level, but there was, in fact, a confirmed problem.
B149	BITE indicated a problem, but there was no problem.

Note: The third or fourth code characters may not be available until after the corrective action taken information is available from the contractor.

MTBM FORMULA

The six versions of the MTBM described in Chapter 2(A) are all calculated using the same basic formula:

$$\text{MTBMA} = \frac{\text{Operating time}}{\text{Quantity of on-equipment maintenance occurrences}}$$

where:

Operating time = system elapsed time indicated (ETI), and quantity of occurrences = the total number of maintenance occurrences during the measured interval.

MTBCF FORMULA

The mean time between critical failures (MTBCF) is an index of the operational mission reliability of the ATD. MTBCF is the total operating time during the evaluation divided by the total number of critical failures during that time and is calculated as follows:

$$\text{MTBCF} = \frac{\text{Operating time}}{\text{Quantity of critical failures}}$$

where:

Operating time = system elapsed time indicated (ETI), and quantity of critical failures = the total number of occurrences which disrupt the completion of mission objectives.

Failures in redundant components are included in MTBM calculations, but are not critical failures so they would not enter into MTBCF calculations. Failures of equipment due to improper maintenance are considered occurrences, but are not critical failures. Secondary failures also are not considered critical, but are considered occurrences and will be included in MTBM calculations. Secondary failures are failures that occur as a result of a failure in some other element or component. For example, a failure in the voltage regulation circuit of the power supply may damage or otherwise cause failures in the components it supplies. Failures due to improper installation are considered occurrences, but are not critical failures.

BITE Rate Formulas

The number of occurrences resulting in the different codes are used as inputs to the following BITE rate formulas.

$$BAIP = \frac{(B135) \times 100}{(B135+B136+B148+B200+B137+B149)}$$

$$BADP = \frac{(B135+B136+B148) \times 100}{(B135+B136+B148+B200+B137+B149)}$$

$$BFDP = \frac{(B200) \times 100}{(B135+B136+B148+B200)}$$

$$BFA = \frac{(B137+B149) \times 100}{(B135+B136+B137+B148+B149)}$$

APPENDIX B

ADDITIONAL MAINTAINABILITY INFORMATION

CONTENTS — PAGE

MAINTAINABILITY COMPUTATIONAL FORMULAS

Mean Time to Repair (MTTR)

$$\text{MTTR} = \frac{\text{Total corrective maintenance clockhours during test period}}{\text{Total number of corrective maintenance actions during the test period}}$$

where the following time guidelines normally apply:

1. Time spent reading TOs, etc., is included if directly related to the maintenance task. Time required to find the TO is typically not included.

2. Time spent accumulating tools necessary for the task is included if they are available in the immediate area.

3. Time spent in preparing the simulator in any way incidental to the task is included.

4. Time spent in direct support of development tasks, e.g., repair of test instrumentation, is not included.

5. If personnel are required on an intermittent or a sequenced basis, the time assessed for the task includes the required standby time only if the standby time is of a type or duration which prevents these personnel from performing other productive tasks.

6. If an item is damaged or maintenance errors are induced by design complexity or improper procedures, the time will be chargeable. When action concerning any of the deficiencies has been completed, the time will not be deleted. However, the maintainability prediction will incorporate the results of any subsequent engineering changes that would affect such times.

7. Corrective maintenance actions will include all those actions documented to repair inherent, induced, and no-defect occurrences (as defined in reliability).

8. MTTR excludes delays due to supply, administration, personnel nonavailability, and transportation, except as provided previously within this section.

MTTR (critical)

$$\text{MTTR (critical)} = \frac{\text{Corrective maintenance manhours expended on critical failures}}{\text{Number of critical failures}}$$

Mean Manhours to Repair (MMTR)

$$\text{MMTR} = \frac{\text{Total corrective maintenance manhours during test period}}{\text{Total number of corrective maintenance actions during the test period}}$$

where time guidelines specified for MTTR apply.

Maintenance Manhours per Training Hour (MMH/TH)

$$\text{MMH/TH} = \frac{\text{Total maintenance manhours}}{\text{Training hours}}$$

where time guidelines for MTTR apply as well as the following:

1. Manhour expenditures include all those manhours expended under the guidelines described under MTTR.

2. Manhour expenditures are only counted during times that the simulator is scheduled for full operational testing, i.e., during the reliability demonstration and operational effectiveness testing.

3. Training hours are counted only for those times that the simulator was used in a full operational condition, i.e., the reliability demonstration and operational effectiveness testing.

4. All manhours expended from beginning of test (reliability demonstration or operational effectiveness tests) until the end of test are counted if they fall under the criteria described under MTTR. End of test will be when all maintenance actions resulting from occurrences during test are completed.

Maintenance Manhours per Operating Hour (MMH/OH)

MMH/OH is computed for the six categories of maintenance action (preventive, inherent, induced, no defect, all failures, and total corrective) using the following formula:

$$MMH/OH = \frac{\text{Direct maintenance manhours (category)}}{\text{Operating hours}}$$

ADDITIONAL MAINTAINABILITY CONSIDERATIONS

When to Start Timing

The process of initiating maintenance-team action after a fault is inserted has been described. However, that description did not indicate when to start timing the maintenance action. This is sometimes complicated by procedures involving the use of computer checkout programs. In some instances these programs take five minutes or more before an answer as to equipment status is indicated. Is this time to be counted as a portion of the restore time, or merely as operational monitoring time? The question becomes crucial if the MTTR requirement is very short, e.g., 15 minutes, and the BITE or automatic checkout time is the greater part of this time. The question must be resolved in the initial test planning phase.

QUALITATIVE MAINTAINABILITY CHECKLIST

1. Are major line-replacement units (LRUs) located to facilitate total system inspection/checkout/troubleshooting?

2. Does system design/installation contribute to ease of maintenance in terms of location, accessibility, etc.. Consider:

   a. Size and access panels/doors, number of and type of fasteners.

   b. Size and weight of components, adequacy of handles or handholds, required span of reach, height above or distance from work surface.

   c. Location of test or servicing points in relation to work surface for test or servicing equipment.

   d. Adequacy of space for necessary support equipment.

3. Are test or servicing points clearly marked to reduce chance of induced error?

4. Are connectors of different size, keyed, or clearly marked to eliminate swapping?

5. Are connectors visible and readily accessible to reduce chance of cross-threading, etc.?

6. Are there hazards in terms of blind spots, sharp edges, exposed electrical connectors/circuitry?

7. Can the system be checked out (operational check, troubleshoot, etc.) by not more than two technicians?

8. Are support equipment/BITE cues and indications easily read and understood?

9. Are environmental conditions such as noxious fumes, high noise levels, extreme temperature, etc., tolerable?

10. Describe other features or requirements not listed above which adversely affect system maintenance:

____

____

____

11. Was the equipment under evaluation considered commercial off-the-shelf equipment?

12. Remarks (explain questions 1-10 that were answered negatively):

____

____

____

APPENDIX C

ADDITIONAL AVAILABILITY INFORMATION

CONTENTS | PAGE

AVAILABILITY COMPUTATIONAL FORMULAS

Inherent Availability

The following formula is used to calculate A_i for the device:

$$A_i = \frac{\text{MTBCF}}{\text{MTBCF+MTTR (critical)}}$$

Scheduling Availability

$$A_s1 = \frac{\text{Number of missions scheduled - number of missions lost + number of missions added}}{\text{Number of missions scheduled + number of missions added}}$$

$$A_s2 = \frac{\text{Mission hours scheduled - hours lost + hours added}}{\text{Mission hours scheduled + hours added}}$$

Mission Capable Rate Chart

Figure C-1 shows a sample mission capable rate data collection chart. Guidelines for completing the chart are as follows:

1. The first entry on the first chart is the time and status of the simulator at initiation of the test period.

2. Whenever the mission capable status changes, enter in the following line the time, new status, primary contributing work-unit code (WUC), a brief description of the cause, and initial the entry.

3. Enter all changes of simulator status, including an N/P status for non-possessed time (if applicable).

4. Use one chart per day, with 2400 hours as the daily closeout time. Date each chart. The last entry of the day should be 2400 hours with a N/C status entry (no-change).

5. After the last entry of the day, total the times for each status and complete the "totals for the day" section.

MISSION CAPABLE CHART

Date ____________________

TIME	STATUS	WUC	COMMENTS	INITIALS

TOTALS FOR THE DAY

A. Possessed Time ______	F. Flyable Time (C+D+E) ______
B. Non-possessed Time ______	G. (NMCM) Sch Time ______
C. FMC Time ______	H. NMCM Unsch Time ______
D. (PMCS) Time ______	I. (NMCS) Time ______
E. (PMCM) Time ______	J. NMC Time (G+H+I) ______

Figure C-1. Sample mission capable rate data collection form.

Mission Capable Rate Formulas

The following data are required to make MCR determinations:

- Possessed clockhours.
- Status clockhours.
- Descriptions, WUCs, and job control numbers of primary causes of status.

Using the data on clockhours per type of status, and the possessed clockhours data, mission capable rates are calculated using the following formulas:

$$\text{FMC} = \frac{\text{FMC clockhours}}{\text{Possessed clockhours}} \times 100$$

$$\text{NMCM scheduled rate} = \frac{\text{NMCM scheduled clockhours}}{\text{Possessed clockhours}} \times 100$$

$$\text{NMCM unscheduled rate} = \frac{\text{NMCM unscheduled clockhours}}{\text{Possessed clockhours}} \times 100$$

$$\text{NMCS rate} = \frac{\text{NMCS clockhours}}{\text{Possessed clockhours}} \times 100$$

$$\text{PMCM rate} = \frac{\text{PMCM clockhours}}{\text{Possessed clockhours}} \times 100$$

$$\text{PMCS rate} = \frac{\text{PMCS clockhours}}{\text{Possessed clockhours}} \times 100$$

$$\text{Flyable rate} = \frac{\text{(PMCM + PMCS + FMC) clockhours}}{\text{Possessed clockhours}} \times 100$$

APPENDIX D

ADDITIONAL LOGISTICS SUPPORTABILITY INFORMATION

CONTENTS	PAGE

MANPOWER CALCULATION PROCEDURE

1. Multiply the number of hours in each shift by the number of personnel required on that shift to get manhours per shift (each shift's minimum manpower situation will be used).

2. Multiply manhours per shift by days per month (of that shift) to get monthly manhours for each situation.

3. Total the monthly manhours for all situations to determine total minimum manhours per month.

4. Divide by the appropriate availability factors to determine minimum manpower.

SUPPORT EQUIPMENT EVALUATION CHECKLIST

1. Is the item easily operated?

2. Was the proposed SE adequate for the task in the following areas:

   a. Depth of test or diagnostic capability versus test required to ensure proper system operation?

   b. Range of SE inputs versus system range of operation?

   c. SE performance parameters (power, accuracy, precision) versus system performance parameters?

3. Are instructions complete and adequate for SE hookup operation and diagnosis?

4. Does the SE (to include diagnostic and BITE routines) test the system (or subsystem) to the same parameters (voltage, frequency, etc.) as those to which the system is supposed to operate?

5. Were indications or cues easily understood?

6. Were diagnostic and/or BITE routines easily initiated?

7. Does this item appear to be corrosion free?

8. Can the proposed SE "stand alone" and not be supported by other common or special units (voltmeters, frequency counters) while being used?

9. Does this item require calibration?

10. Does this item use software (computer programming)?

11. Are there similar maintenance or service functions performed by other SE?

12. Is there an alternate method which would not require use of this equipment?

13. Was a maintenance task performed using this equipment?

14. Is there a possible safety hazard at any time during transportation or positioning and using this equipment?

(Any answer of "no" to any of the questions from 1 to 8, and any answer of "yes" to any of the questions from 9 to 14 requires explanation on back.)

TECHNICAL DATA CONTENT CHECKLIST

Sat/Unsat (S/U)

_1. Manuals identify all units & assemblies by location & function.

_2. Manuals provide schematics & wiring diagrams at least to the LRU.

_3. Manuals describe all uncommon parts, tools, codes, or test units.

_4. Manuals tell how to detect, localize, isolate, correct, checkout.

_5. Manuals explain what to check, what to expect & how to correct.

_6. Manuals tell what may go wrong, how to prevent & how to recover.

_7. Manuals accurately list men, tools, materiel used in each task.

_8. Manuals layout cues/aids effective & efficient troubleshooting.

_9. Manuals clearly describe access, breakdown & assembly methods.

_10. All emergency conditions, procedures & escape routes are shown.

_11. All adjust, align, calibrate & checkout procedures are shown.

_12. Special instructions are given for unusual climates/conditions.

_13. Measurement data references methods/equipment to be used.

_14. Data are logically organized, quickly found, & readily used.

_15. Manual terms/symbols are consistent with maintenance data system.

_16. All procedures are consistent with expected use & failure rates.

_17. All procedures are consistent with planned manning & workloads.

_18. All procedures reflect supply, handling, & storage practices.

_19. Maintenance block diagrams are provided for each equipment item.

_20. Diagrams describe interconnections & relationships between items.

_21. Diagrams identify input-output connections between subassemblies.

_22. Diagrams give designations for terminals, jacks & test points.

_23. Diagrams show voltage, current, & waveform at each test point.

_24. Diagrams reflect, are compatible with, diagnostic techniques.

_25. All materials are consistent with system maintenance concepts.

TECHNICAL DATA STYLE CHECKLIST

Sat/Unsat (S/U)

_1. Manuals are planned, designed, distributed for easy, daily use.

_2. Print is [illegible]; material durable; no transparent/glossy paper.

_3. Where possible, pocket manuals contain specialist specific data.

_4. Major portions of the manual are tabbed and/or subject indexed.

_5. Both detailed table of contents & subject index are provided.

6. Indexes are symptom oriented, to lead from trouble to solution.

7. Instructions are in step-by-step rather than narrative format.

8. Each procedure in the manual has been tried, validated.

9. Maintenance procedures avoid unnecessary testing or handling.

10. Instructions balance workload among personnel, between hands.

11. Instructions fix action location before describing the action.

12. Tools, testers, & material are listed at top of each instruction.

13. Dial, meter, switch settings are given wherever appropriate.

14. Warnings & cautions are given in the sequence encountered.

15. Feedback loops lead to discovery/correction of probable errors.

16. Technical data are clear, unambiguous, require no interpolation.

17. All language, words, & symbols are short, familiar, & concise.

18. Paragraphs are short with frequent run-in & side headings.

19. Titles, subtitles, & headings clearly indicate area of coverage.

20. Bold type, underlining, and spacing for salient key words & thoughts.

21. Tables, charts, & illustrations are used wherever practicable.

22. Photographs show unfamiliar detail, are retouched to aid reader.

23. Drawings illustrate familiar items, show movement, orientation.

24. Exploded views show part location, disassembly methods, etc.

25. Data are accurate & up-to-date, but revision means are provided.

FACILITIES EVALUATION CHECKLIST

Sat/Unsat (S/U)

_1. Facility layout minimizes maintenance/operations interference.

_2. Layout minimizes place-to-place movement of men & equipment.

_3. Layout provides adequate bench maintenance, shop, storage space.

_4. Layout allows visual & voice contact between team members.

_5. Layout allows access to most sides of all items of equipment.

_6. All spacing is planned for likely clothing, loads, clutter, etc.

_7. Stockroom/tool crib locations are convenient to all work areas.

_8. Special storage is provided for hazardous or contaminable items.

_9. Kick-space, knee room, writing surfaces, etc. are adequate.

_10. Passageways are adequate for carts, stands, etc. & their loads.

_11. Passages, doors, corners allow complete removal of largest item.

_12. Passages/doors allow easy access to & escape from all work-places.

_13. Workspace is planned primarily for standing or sitting tasks.

_14. Workspace is adequate despite testers, open drawers, or doors.

_15. Workspaces are free of hazards, obstructions, sharp edges, etc.

_16. Space is adequate for required stooping, crawling, climbing, etc.

_17. Chairs are provided where men rest or sit [illegible] of the shift.

_18. Illumination is adequate on work surfaces, displays & passages.

_19. Internal paint & lighting assist maintenance; glare is avoided.

__20. Auxiliary & safety lights are provided [illegible], etc.

__21. Noise levels are tolerable, do not [illegible] tasks.

__22. Vibration effects on tools, displays, labels, etc., are tolerable.

__23. Interior temperature/humidity is controlled [illegible] preferred ranges.

__24. Equipment air conditioning is controllable during [illegible].

TRANSPORTATION AND HANDLING CHECKLIST

1. Is the packaging adequate to prevent damage?

2. Is package design compatible with storage preservation requirements?

3. Are handling requirements minimized?

4. Are packaging material and procedures simple and reusable?

5. Are applicable markings provided?

6. Are personnel safety cautions, warnings [illegible] provided?

7. Are system records properly [illegible]

8. Are hazardous dangerous [illegible] packaged, marked, [illegible] properly?

9. Was the mode of transportation adequate in all respects?

10. Is the item transportable by [illegible] and [illegible]

11. Was transportation adequate [illegible]

12. Was any damage detected which [illegible] tation or handling?

13. Were carrier's [illegible] requirements?

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OPERATIONAL TEST AND EVALUATION HANDBOOK FOR AIRCREW TRAINING D--ETC(U)
FEB 82 W V HAGIN, S R OSBORNE F33615-78-C-0063
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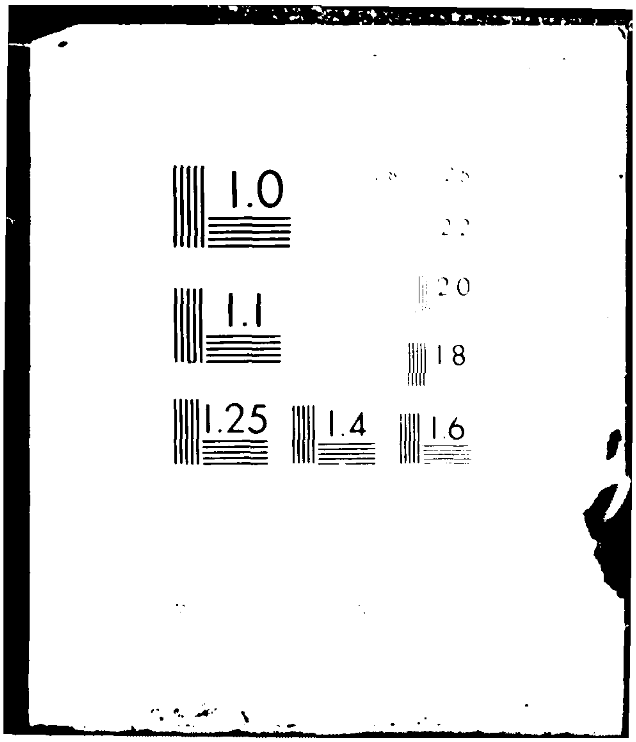
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14. Were containers marked with center of balance, sling-lift facilities, forklift entry points, etc., when required?

15. Is the supply of packaging material complete in terms of type of material and adequate in amount?

16. Are space and tools sufficient to allow the construction of crates and containers?

17. Is heavy capacity equipment such as forklifts, elevators, and hoists sufficient for most requirements?

18. Are loading/unloading docks adequate?

19. Are special physical packaging or handling precautions provided (if required)?

20. Are security requirements provided for?

21. Is environmental protection adequate?

22. Have written procedures been provided for on-site use?

23. Do the procedures employed on-site provide for:

   a. Proper labeling, to include handling precautions, addresses, etc.?

   b. Positive security or inventory?

   c. Placement of items in additional security areas, or areas which provide added environmental protection?

24. Have procedures been established for military/commercial shipment?

25. Are time-sensitive items (i.e., time change items, items with specified shelf life, etc.) identified?

26. Remarks:

APPENDIX E

O&S COST EVALUATION FORMULAS

CONTENTS PAGE

O&S COST EVALUATION FORMULAS

Simulator Maintenance Manpower Costs

Cost 1 = (no. of airmen) X (airman pay factor)

Cost 2 = (no. of officers) X (officer pay factor)

Cost 3 = (no. of civilians) X (civilian pay factor)

Cost 4 = (no. of CFS [contractor field service] and FSR [field service representatives]) X (sum of O&M contract costs per man year)

Cost Tot = Cost 1 + Cost 2 + Cost 3 + Cost 4

Replenishment Spares

$$\text{Cost} = \frac{\text{UE X OP hrs/year X cond rate X UC + UCi}}{\text{MTBM (induced)}}$$

where:

- UE is the unit equipment (number of simulators per wing or squadron).
- OP hrs/year is the scheduled number of individual annual simulator operating hours.
- Cond rate is the replenishment spares predicted condemnation rate.
- UC is the unit cost of the replenishment spares.
- MTBM (induced) is the predicted MTBM of the replenishment spares.
- UCi is initial spares acquisition cost by unit.

Simulator Maintenance Materiel

Cost = UE X OH X MPOH

where:

- UE is the unit equipment (number of simulators per wing or squadron).
- OH is the annual operating hours per simulator.
- MPOH is the maintenance materiel expended per operating hour.

Support Equipment

Cost = UE X (SE cost factor)

where:

- UE is the unit equipment (number of simulators per wing or squadron).
- SE cost factor is the cost of requisition and replacement of simulator SE.

Simulator Facility

Cost = AREA X BFAC

where:

- AREA is the facility floorspace required in direct support of ATD operations and maintenance, including the floorspace consumed by the trainer itself. This variable is expressed in square feet.
- BFAC is the base peculiar O&M planning factor which is used to account for geographical differences when programming facilities maintenance cost. This factor is expressed in current year dollars.

Electrical Power

Cost = PWR X PCOST X OPHRS X UE

where:

- PWR is the predicted hourly electrical power required for operation and maintenance of a simulator.
- PCOST is the cost of the above electrical power per unit.
- OPHRS is the predicted annual operating hours of a simulator.
- UE is the unit equipment (number of simulators per wing or squadron).

APPENDIX F

SOFTWARE MAINTAINABILITY QUESTIONNAIRES

CONTENTS

SOFTWARE DOCUMENTATION QUESTIONNAIRE

MODULARITY QUESTIONS

1. The documentation includes a separate part for the description of external interfaces.

2. The documentation includes a separate part for the description of each major function.

3. The documentation includes a separate part for the description of the program global data base.

4. Major parts of the documentation are essentially self-contained.

5. The documentation has been physically separated into (sets of) volumes each with a distinct purpose.

6. The documentation indicates that each global data structure is partitioned into functionally related sets of variables.

7. The documentation indicates that storage locations are not used for more than one type of data structure.

8. The program control flow is organized in a top down hierarchical tree pattern.

9. The documentation indicates that program initialization processing is done by one (set of) module(s) designed exclusively for that purpose.

10. The documentation indicates that program termination processing is done by one (set of) module(s) designed exclusively for that purpose.

11. The documentation indicates that program I/O is done by one (set of) module(s) designed exclusively for that purpose.

12. The documentation indicates that program error processing is done by one set of modules designed exclusively for that purpose.

DESCRIPTIVENESS QUESTIONS

13. Each physically separate part of the documentation includes a useful table of contents.

14. Each physically separate part of the documentation includes a useful glossary of major terms and acronyms unique to that document.

15. Each physically separate part of the documentation includes a useful index.

16. It is easy to locate specific information within the documentation.

17. The documentation includes a useful version description document.

18. A useful master list is available which identifies all software documentation.

19. Any dynamic allocation of resources (storage, timing, priority, hardware services, etc.) is explained in the documentation.

20. Timing requirements for each major function of the program are explained in the documentation.

21. Storage requirements for each major function of the program are explained in the documentation.

22. The inputs to each module are explained in the documentation.

23. The processing done by each module is explained in the documentation.

24. The outputs from each module are explained in the documentation.

25. Special processing considerations (error, interrupt, etc.) of each module are explained in the documentation.

26. There is a flow chart (or equivalent) for each module which adequately illustrates the inputs, general processing, and outputs for the module.

27. Program initialization and termination processing is explained.

28. Recovery from externally generated error conditions which could affect the program is explained.

29. The process of recovering from internally generated error conditions is explained.

30. Input of program data is explained.

31. Output of program data is explained.

32. There is a useful set of charts which show the general program control and data flow hierarchy among all modules.

33. There is a master list (chart, table, section, etc.) identifying where each global variable is used.

34. The global variable master list includes information about each global variable such as type, range, scaling, units, etc.

35. The use of any complex mathematical model (technique, algorithm) is explained in the documentation.

36. The documentation on each complex mathematical model includes information such as a derivation, accuracy requirements, stability considerations and references.

CONSISTENCY QUESTIONS

37. It appears that a useful set of standards has been followed for the development of the documentation.

38. It appears that a set of standards has been followed for the construction of all (program and module) flowcharts (or equivalent).

39. Documentation of each major functional part of the program follows the same format.

40. The format of the documentation reflects the organization of the program.

41. It appears that programming conventions have been established for the interfacing of modules.

42. It appears that programming conventions have been established for I/O processing.

43. It appears that design conventions have been established for error processing.

44. A naming convention for modules appears to have been used.

45. A naming convention for global variables appears to have been used.

SIMPLICITY QUESTIONS

46. The terminology used in the documentation to describe the program is easily understood.

47. The documentation is physically organized as a systematic description of the program from levels of less detail to levels of more detail.

48. Each part (sentence, paragraph, subsection, section, chapter, volume, etc.) of the documentation tends to express one central idea.

49. The amount of cross referencing among parts of the documentation contributes to the understandability of the program description.

50. The documentation indicates that the program source language is a high order language (HOL).

51. The documentation indicates that the use of recursive/reentrant programming techniques is not excessive.

52. The documentation indicates that each program module is designed to perform only one major function.

53. The documentation indicates that resource (storage, timing, tape drives, disks, consoles, etc.) allocation is fixed throughout program execution.

54. The documentation indicates that the control flow among modules is easy to follow.

55. The timing scheme designed for the program is easily understood from the documentation.

56. The program is designed so that modules are not interrupted during execution.

57. It is evident from the documentation that a knowledge of mathematics beyond basic algebra is not required to understand the mathematical functions performed by the program.

EXPANDABILITY QUESTIONS

58. A numbering scheme has been adopted which allows for easy addition or deletion of narrative parts of the documentation.

59. Graphic materials (figures, charts, lists, etc.) are physically separate (e.g., on separate pages) from narrative description.

60. A numbering scheme has been adopted which allows for easy addition or deletion of graphic materials.

61. The program timing scheme appears to be flexible enough to allow for modifications (e.g., reorganization, addition, deletion of functional parts).

62. There is a reasonable time margin for each major program function (rate group, time slice, priority level, etc.).

63. Documentation narrative explains the procedures for altering basic data storage sizes.

64. The program has been designed to allow for an increase in storage utilized before storage capability is exceeded.

65. Those modules dependent upon data structure sizes are identified.

66. The program has been designed so that functional parts may be easily added or deleted.

INSTRUMENTATION QUESTIONS

67. There is a separate part of the documentation for the description of a program test plan.

68. There is a separate part of the documentation for the description of sample test data.

69. There is a separate part of the documentation for the description of program support tools which would aid in testing program.

70. A set of test procedures to be used for program checkout is explained.

71. The set of test procedures provides useful unit testing information.

72. The set of test procedures provides useful information on limitations/incompleteness.

73. The program has been designed with the capability to display inputs and outputs in summary form.

74. The documentation describes a standardized set of program test data (input and ouput) that has been designed to exercise the program.

75. The documentation indicates that the program has been designed to include software test probes to aid in identifying processing performance.

76. Error checking within the program has been designed to include such features as diagnostic reporting, I/O parameter checking, runtime index range checking, etc.

GENERAL QUESTIONS

77. Modularity as reflected in the program documentation contributes to the maintainability of the program.

78. Descriptiveness as reflected in the program documentation contributes to the maintainability of the program.

79. Consistency as reflected in the program documentation contributes to the maintainability of the program.

80. Simplicity as reflected in the program documentation contributes to the maintainability of the program.

81. Expandability as reflected in the program documentation contributes to the maintainability of the program.

82. Instrumentation as reflected in the program documentation contributes to the maintainability of the program.

83. Overall, it appears that the characteristics of the program documentation contribute to the maintainability of the program.

SOFTWARE SOURCE LISTING QUESTIONNAIRE

MODULARITY QUESTIONS

1. Functionally related data elements have been organized into logical data structures.
2. The concepts of structured programming have been applied to the control structures in this module.
3. The use of techniques which involve the sharing of memory locations (e.g., overlay, equivalence, same area) is not excessive.
4. The use of global data in this module is not excessive.
5. The number of entry points of this module is not excessive.
6. The number of exit points of this module is not excessive.
7. This module performs only related functional tasks.
8. Each functional task of this module is an easily recognizable block of code.
9. It appears that each iteration block within this module has a single entry point.
10. It appears that each iteration block within this module has a single exit point.
11. It appears that each decision block within this module has a single entry point.
12. It appears that each decision block within this module has a single exit point.
13. When this module completes execution, control is returned to the calling module.
14. The use of the same variable for both input and output is not excessive in this module.

DESCRIPTIVENESS QUESTIONS

15. Inputs to this module are described in a preface block.
16. Outputs from this module are described in a preface block.

17. The purpose of this module is described in a preface block.

18. Modules which call this module are identified in a preface block.

19. Modules which are called by this module are identified in a preface block.

20. Limitations (accuracy, timing, data I/O, etc.) are described as appropriate in a preface block.

21. Any special processing (e.g., multiple entry/exit, error handling, algorithm peculiarities, etc.) is described in the preface block and is understandable.

22. Documentation information (module name, programmer, algorithm references, revision data, etc.) is identified as appropriate in a preface block.

23. The comments in this module contain useful information.

24. The quantity of comments does not detract from the legibility of the source listings.

25. Transfers of control and destinations are clearly explained.

26. Machine-dependencies are clearly commented.

27. Imbedded comments describe each function (block of code) within this module.

28. Attributes of each variable used in this module are described by comments and/or source language declarations.

29. Error processing/exits are clearly identified and explained.

30. It appears that a standard for module organization has been followed within this module.

31. Variables are declared in a specification/declaration section.

32. Variable names are descriptive of their functional use.

33. The module code is indented within control structures to show control flow.

34. Statement labels have been named in a manner which facilitates locating a label in the source listing.

35. The machine cross reference listings appear to be useful.

36. This module's flow chart represents the logic control flow as shown in this module's source listing.

37. This module's flow chart represents the data flow as shown in this module's source listing.

38. The labels in this module's flow chart and the statement labels in this module's source listing are in agreement.

39. The inputs to this module as described in the documentation correspond to the inputs as shown in this module's source listing.

40. The outputs from this module as described in the documentation correspond to the outputs as shown in the module's source listing.

41. The order of arguments for this module as described in the documentation corresponds to the order of arguments as shown in this module's source listing.

42. The module processing as described in the documentation corresponds to the implemented processing as shown in this module's source listing.

43. The programming conventions established in the documentation for source code development have been followed within this module.

44. The delineation of comments is uniform within sections of this module.

45. Each variable in this module is considered to be of one (and only one) data type for all occurrences.

46. Each variable in this module has only one function.

47. Global variables are distinguishable from local variables by a naming convention.

48. The use of indentation is uniform within this module.

49. The information in the preface block is consistent with the associated source code.

SIMPLICITY QUESTIONS

50. The source language for this module is a high order language (HOL).

51. The control flow of this module is essentially from top to bottom.

52. This module contains very little extraneous code.

53. There is minimal use of specialized coding techniques in this module.

54. Esoteric (clever) programming is avoided in this module.

55. GO TO-like branch statements in this module are used only where essential.

56. There is reasonable use of statement labels in this module.

57. A knowledge of mathematics beyond basic algebra is not required to understand the mathematical functions performed by this module.

58. This module contains a minimal number of compound data structures.

59. This module contains a minimal number of compound control structures.

60. Each physical source line in this module contains at most one executable source statement.

61. There is a minimal use of compound Boolean expressions in this module.

62. The number of expressions used to control branching in this module is manageable.

63. The number of unique operators in this module is manageable.

64. The number of unique operands in this module is manageable.

65. The number of executable statements in this module is manageable.

EXPANDABILITY QUESTIONS

66. There is a minimal mixing of I/O functions and other application functions in this module.

67. There is a minimal mixing of machine dependent functions and other application functions in this module.

68. Constants used more than once in this module are parameterized.

69. There is minimal use of processing-dependent code (e.g., relative addressing, self-modifying code, etc.) in this module.

70. The size of any data structure which affects the processing logic of this module is parameterized.

71. Any constants (e.g., accuracy, convergence, timing) which affect processing in this module are parameterized.

72. The contribution of this module to the consumption of frame time can be determined.

73. The volume of data which this module can process does not appear to be limited.

74. It appears that functional parts could be easily inserted, deleted, or replaced within this module.

INSTRUMENTATION QUESTIONS

75. This module contains checks for possible out-of-bound array subscripts.

76. This module contains checks to detect possible undefined operations.

77. This module contains a minimal amount of code which would require lower-level detailed testing.

78. Source listing comments suggest or reference input data and associated output results for use in testing this module.

79. Diagnostic messages/error codes are output when an illegal input to this module is encountered.

80. Diagnostic messages/error codes are output whenever an internal module failure could occur.

81. Intermediate results within this module can be selectively collected for display.

82. Aids exist in or can be easily inserted into the module's source code for the purpose of tracing the logical flow of control.

GENERAL QUESTIONS

83. Modularity as reflected in this module's source listing contributes to the maintainability of this module.

84. Descriptiveness as reflected in this module's source listing contributes to the maintainability of this module.

85. Consistency as reflected in this module's source listing and between the source listing and documentation contributes to the maintainability of this module.

86. Simplicity as reflected in this module's source listing contributes to the maintainability of this module.

87. Expandability as reflected in this module's source listing contributes to the maintainability of this module.

88. Instrumentation as reflected in this module's source listing contributes to the maintainability of this module.

89. Overall it appears that the characteristics of this module's source listing contribute to the maintainability of this module.

APPENDIX G

SOFTWARE USABILITY QUESTIONNAIRE

CONTENTS

SOFTWARE OPERATOR-MACHINE INTERFACE QUESTIONNAIRE

ASSURABILITY QUESTIONS

Assurability: the extent that the system aids the operator in validating data, avoiding errors, and correcting errors once made.

1. Operator input errors do not cause system failures.
2. Operator input errors are detected.
3. The causes of input errors are displayed to the operator.
4. The action required to correct an operator input error is displayed to the operator.
5. Input errors are easily corrected.
6. Input errors are quickly corrected.
7. The operator can verify input before execution entry.
8. Mission peculiar data entered by the operator is checked for validity.
9. The data entry display has a cursor or pointer.
10. The operator is able to correct mistyped characters with a backspace key.
11. The system does not require the operator to copy information by hand.
12. [illegible] and interrupts do not have detrimental side effects.
13. Selecting a device off-line does not have detrimental side effects.
14. The system automatically ceases executive if internal errors are detected (data-base protection).
15. The operator is alerted to faults within the system.
16. The causes of system halts are displayed to the operator.

CONTROLLABILITY QUESTIONS

Controllability: the extent that the system allows the operator to direct the operations of the machine.

17. The operator can interrupt and resume automatic processes.

18. The operator has task abort capabilities available.

19. The operator may initiate selected self-test systems.

20. The operator may send output data to various devices.

21. The operator can ask for and receive the current status of operation.

22. The operator can select the type of information shown on the display.

23. The operator may command various displays of system status.

24. The operator may control the amount of required explanatory text, both input and output.

25. The operator may edit the data [illegible] to use by the system.

26. The operator may create and execute strings of commands as a single command.

27. The operator can command visibility (stepped execution) of automatic processes.

28. The operator may command different modes of operation.

29. The operator may control the type and quantity of output.

30. Bypass procedures are available so that in cases of partial system failure the more important system functions can still be performed.

WORKLOAD REASONABILITY QUESTIONS

Workload reasonability: the extent that the tasks required of the operator are within the operator's capabilities and the extent to which the operator performs a useful, meaningful role.

31. It is easy to enter mission (task) peculiar data.

32. Data preparation is usually performed using on-line devices.

33. The system will accept free-format commands and data.

34. Menu techniques are used to aid the operator in making decisions.

35. The system may be operated without reference to manuals during normal operations.

36. The operator needs to memorize a comfortably small number of commands in order to effectively operate the system.

37. Messages to the operator are easy to understand.

38. The device used to send messages to the operator provides information at a rate comfortable to the operator.

39. The number of messages presented to the operator at one time is small.

40. The system software may be reloaded quickly and easily.

41. The system software needs to be reloaded infrequently.

42. System warm-up time is small.

43. The operator's manual makes minimal use of cross-references.

44. It is easy to locate specific information within the operator's manual.

45. The operator's manual is a reasonable size.

46. The operator performs no tedious functions which could be handled by the system.

47. The operator is rarely bored and performs a "dynamic" function.

48. The operator is not forced to wait for the machine to respond.

49. The operator is not a slave to the machine.

DESCRIPTIVENESS QUESTIONS

<u>Descriptiveness</u>: the extent to which the operator has available detailed explanations of every function the operator performs and every function the machine performs.

50. Power-on and power-off procedures are well documented.

51. The operator has adequate instructions for handling emergencies.

52. Legitimate responses for all conditions are explained.

53. The software provides a question-answer type operator aid.

54. The system will explain each command upon user request.

55. Explanations of how to interpret all output data are available.

56. The operator is adequately alerted when the system requires operator action.

57. The machine gives the operator decision aids if tasks cannot be executed as ordered.

58. The version number (revision number) of the software is readily available to the operator from the system.

59. Data base configuration data are readily available to the operator.

60. All documents the operator requires (including cross-references) are easily available to him.

61. The operator's manual clearly explains the normal sequential steps of operation.

62. The operator's manual contains a useful table of contents.

63. The operator's manual contains a useful index.

64. The operator's manual contains a useful glossary.

CONSISTENCY QUESTIONS

Consistency: the extent that the behavior of the machine and documentation correspond to the expectations of the operator.

65. Operator entered commands are systematically formatted.

66. The command language is a standardized language.

67. Requirements for operator input agree with the operator's manual.

68. Messages to the operator are systematically formatted.

69. Messages requiring action by the operator are always highlighted in some fashion.

70. Operator entries always result in some type of response.

71. Response times are similar for groups of similar activities.

72. System performance corresponds with documented performance (specifications, user's manuals, etc.).

73. Checklists agree with the operator's manual.

74. Operator's manuals are systematically formatted.

SIMPLICITY QUESTIONS

Simplicity: the extent that information presented to the operator or entered by the operator is grouped into short, readily understandable structures.

75. The operator needs to know only one command language.

76. Operator entered instructions are relatively short.

77. It is easy to understand actions required of the operator.

78. Messages to the operator are short.

79. Each new message contains only one idea to which the operator must respond.

80. Only essential or useful information is displayed to the operator.

81. The display is not overcrowded (unless commanded to be so).

82. Difficult words or characters are rarely used.

83. Data structures are easily understandable.

84. The operator has appropriate checklists available.

85. The number of checklists required is manageable.

86. The operator's manual is a single volume (except for checklists).

87. The operator's manual is easy to understand.

88. Alternatives to normal operating sequences are described separately (not embedded within normal procedures).

GENERAL QUESTIONS

Note: The following questions relate to the evaluator's general impression of the computer program's contribution to system usability or effectiveness. Definitions of the test factors should be reviewed before completing these questions.

89. The concepts of Assurability as implemented in the system contribute to usability of the system.

90. The concepts of Controllability as implemented in the system contribute to usability of the system.

91. The concepts of Workload Reasonability as implemented in the system contribute to usability of the system.

92. The concepts of Descriptiveness as implemented in the system contribute to usability of the system.

93. The concepts of Consistency as implemented in the system contribute to usability of the system.

94. The concepts of Simplicity as implemented in the system contribute to usability of the system.

95. Overall, it appears that the operator-machine interface has been well designed.

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